

FE-I1 Modules: Comparing AMS and IZM

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Comparisons of measurements for AMS and IZM bumps

- Noise and Leakage versus VDet
- Noise performance for different types of pixels
- Timewalk performance for different types of pixels
- Comparison of absolute TOT from Am241 source scans

Results from first Tesla module:

- Noise performance with grounded and floating DGrid
- Don't use more of these Tesla sensors for modules for testbeam/irradiation !

System Test and New Modules:

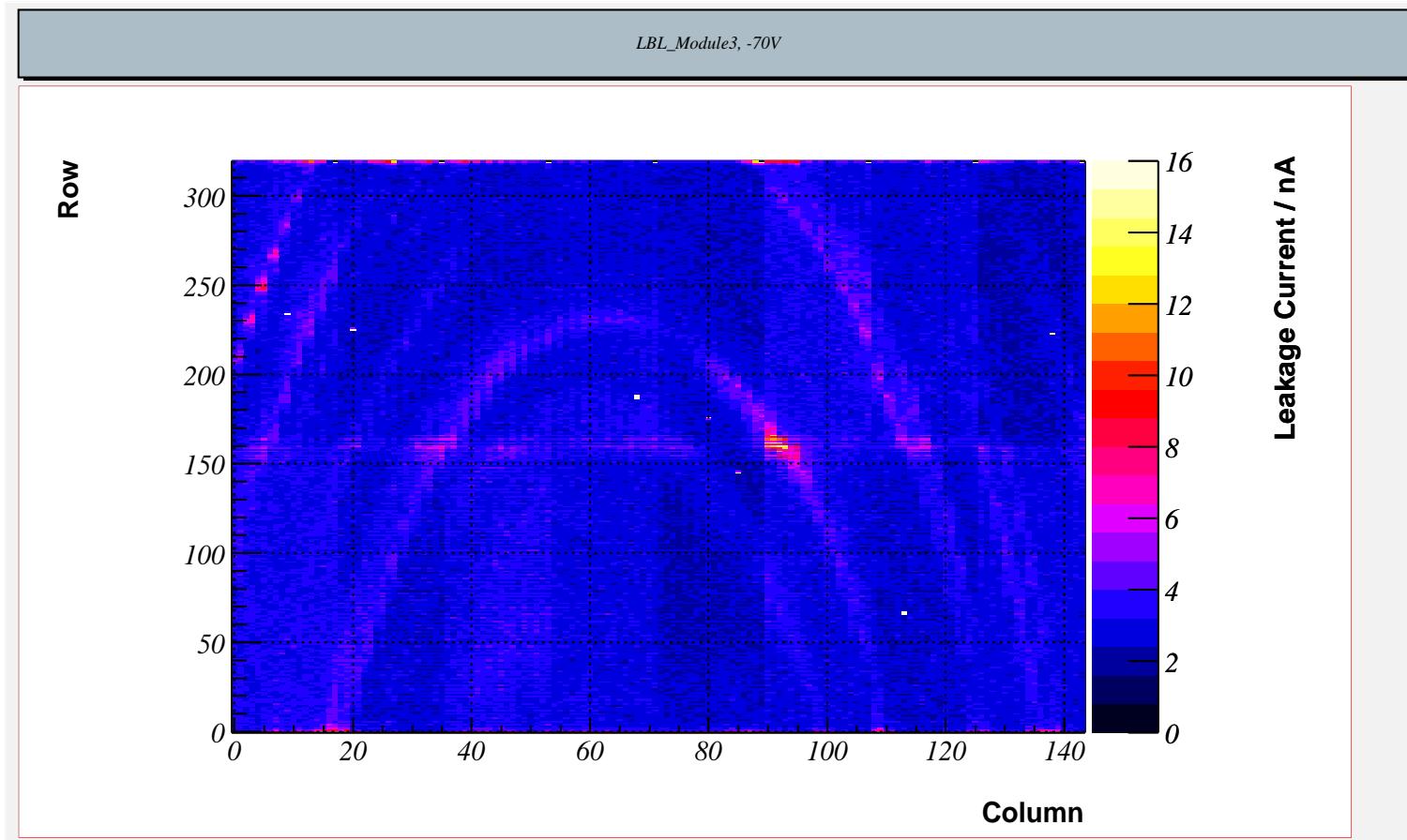
- LBL_8 has bad chip (poor analog performance, not IVDDA problem) in "perfect" bare module
- System test should start with LBL_3, LBL_4, and LBL_7 next week

Module Performance at small VDet

Correlate leakage current and noise:

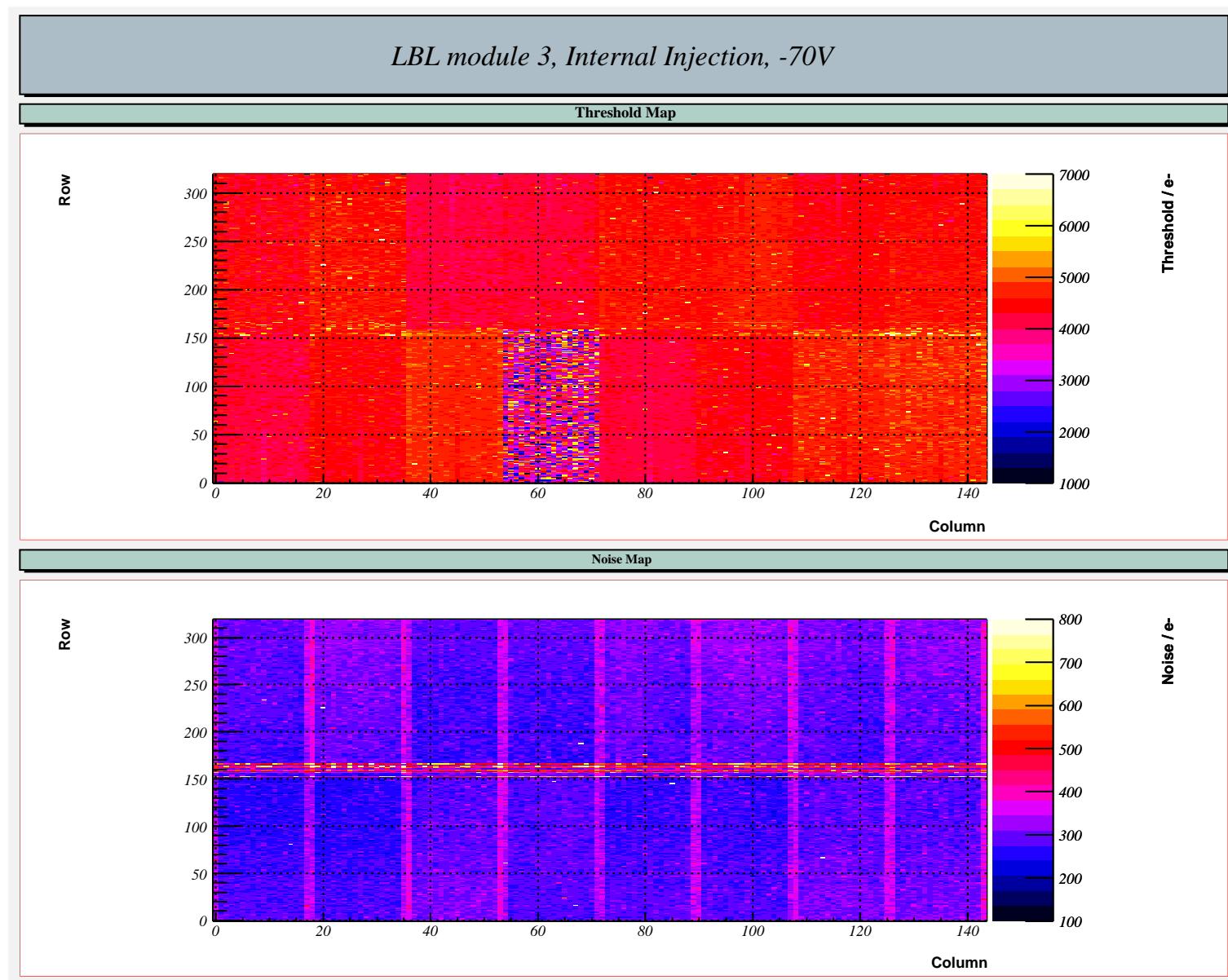
- Well known that for unirradiated IZM modules, as the bias voltage is lowered below the depletion voltage, all pixels rapidly stop working. This serves as one of many techniques for testing bump connectivity.
- Model for sensor near depletion voltage is that there is a thin layer of undepleted silicon around the n+ implants which has sufficiently low sheet resistance that it shorts individual pixels together and to the grounded guard ring.
- Simple model of a resistor from preamp input to ground injects leakage current. Preamp sits at 1V, so already a $10M\Omega$ resistor would inject 100nA leakage.
- This behavior can be clearly seen for IZM module, where right at the depletion voltage, there are large correlations between leakage current and noise.
- The behavior of the AMS modules is completely different, with very little leakage current observed below depletion, and “patchy” behavior, with some chips having a much lower apparent bump resistance (and hence higher noise and leakage) than others.

- Leakage Current map at 70V bias for LBL_3 (IZM):



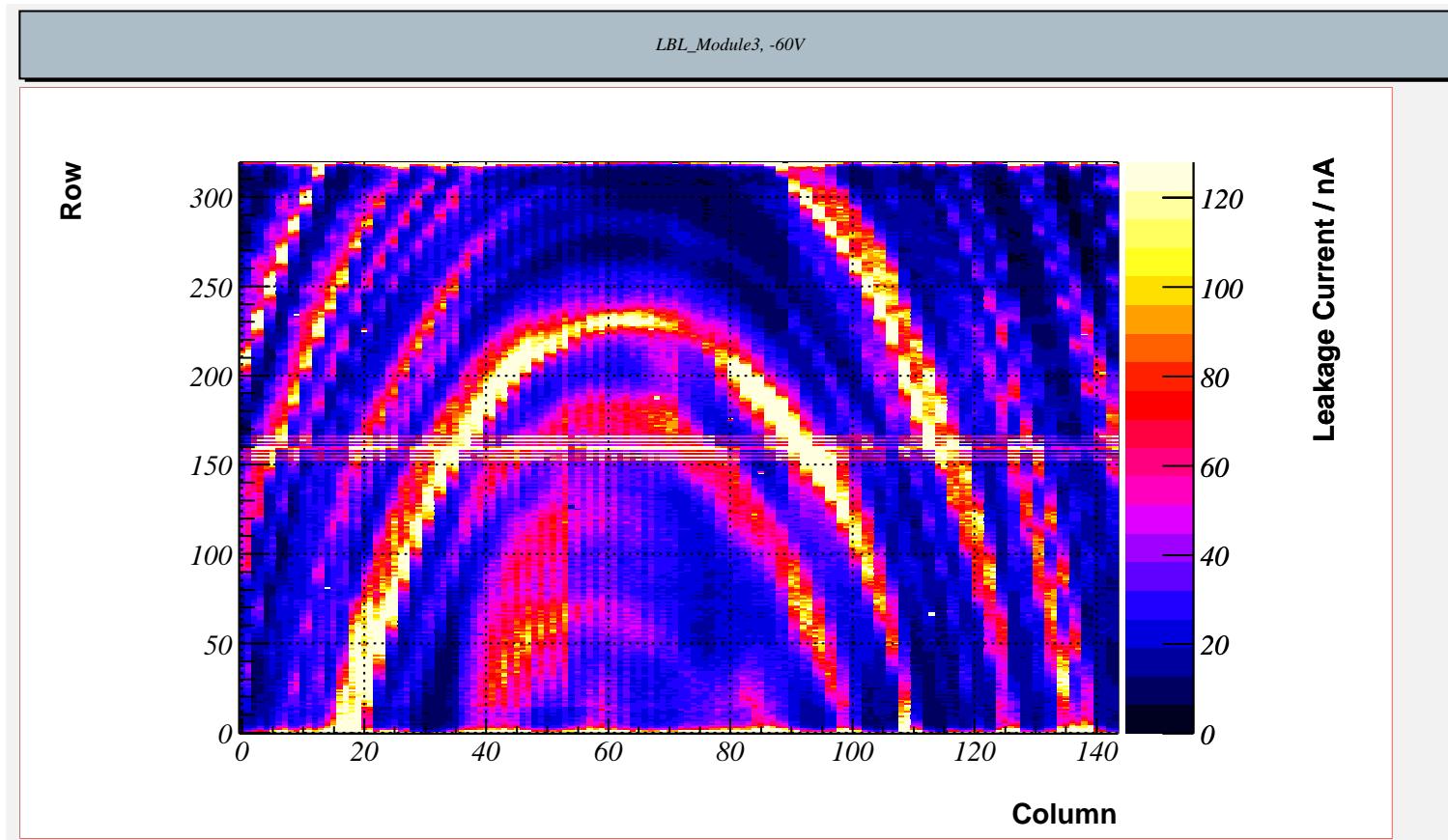
- Can see the beginnings of excess leakage current, following circular pattern.

- Threshold Map at 70V bias for LBL_3 (IZM):



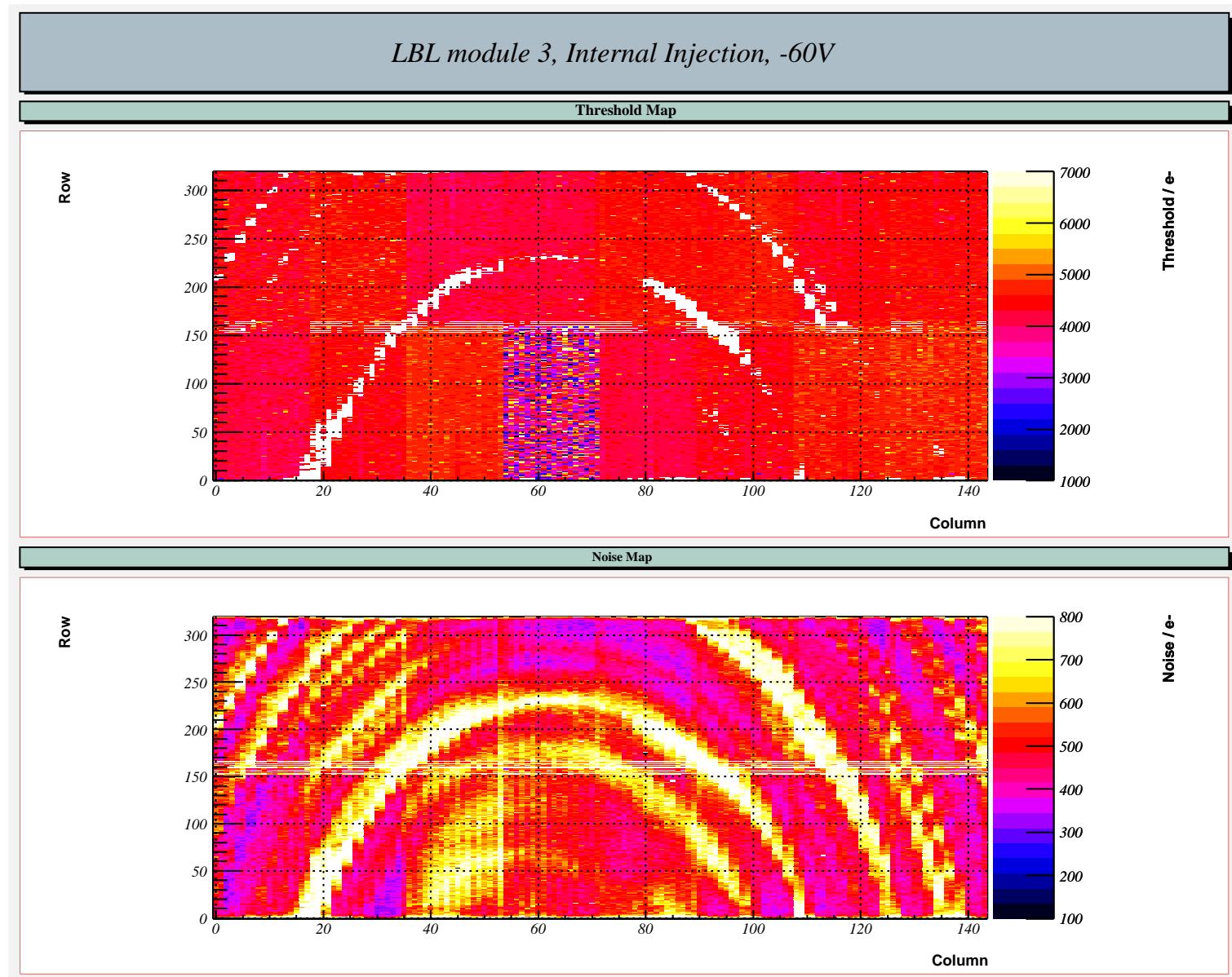
- Threshold and noise performance looks perfectly normal still.

- Leakage Current map at 60V bias for LBL_3 (IZM):



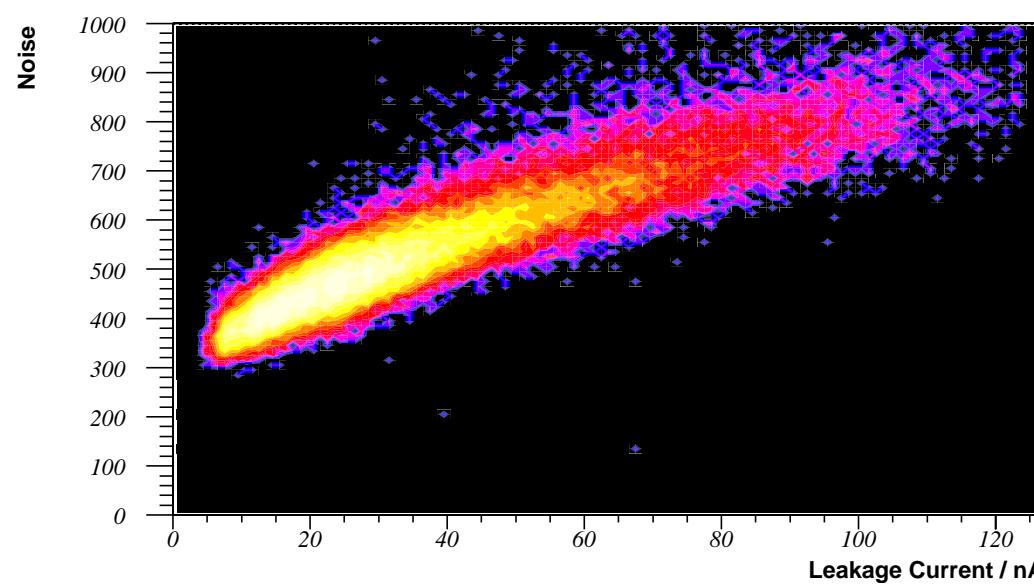
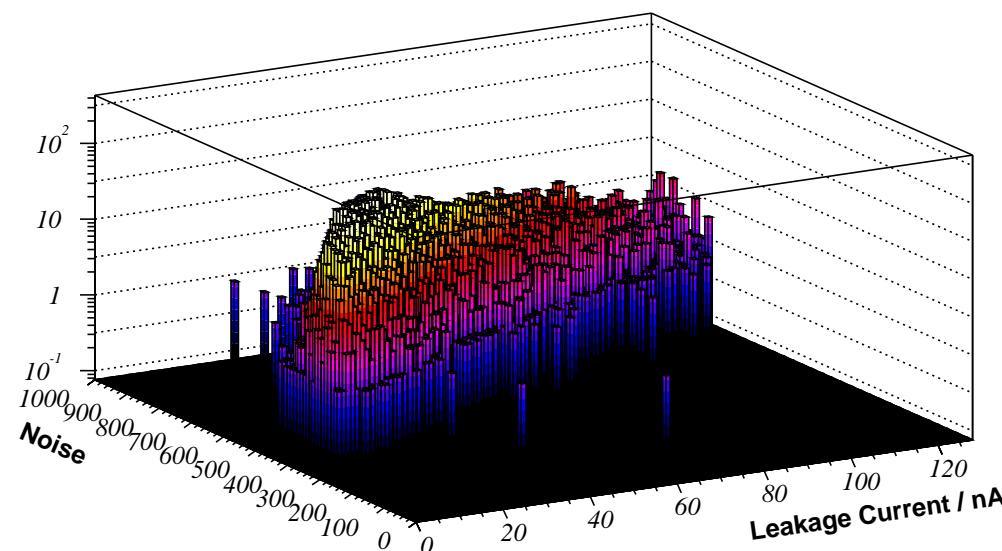
- Can see very significant excess leakage current, following circular pattern typical of sensor doping variations.

- Threshold Map at 60V bias for LBL_3 (IZM):



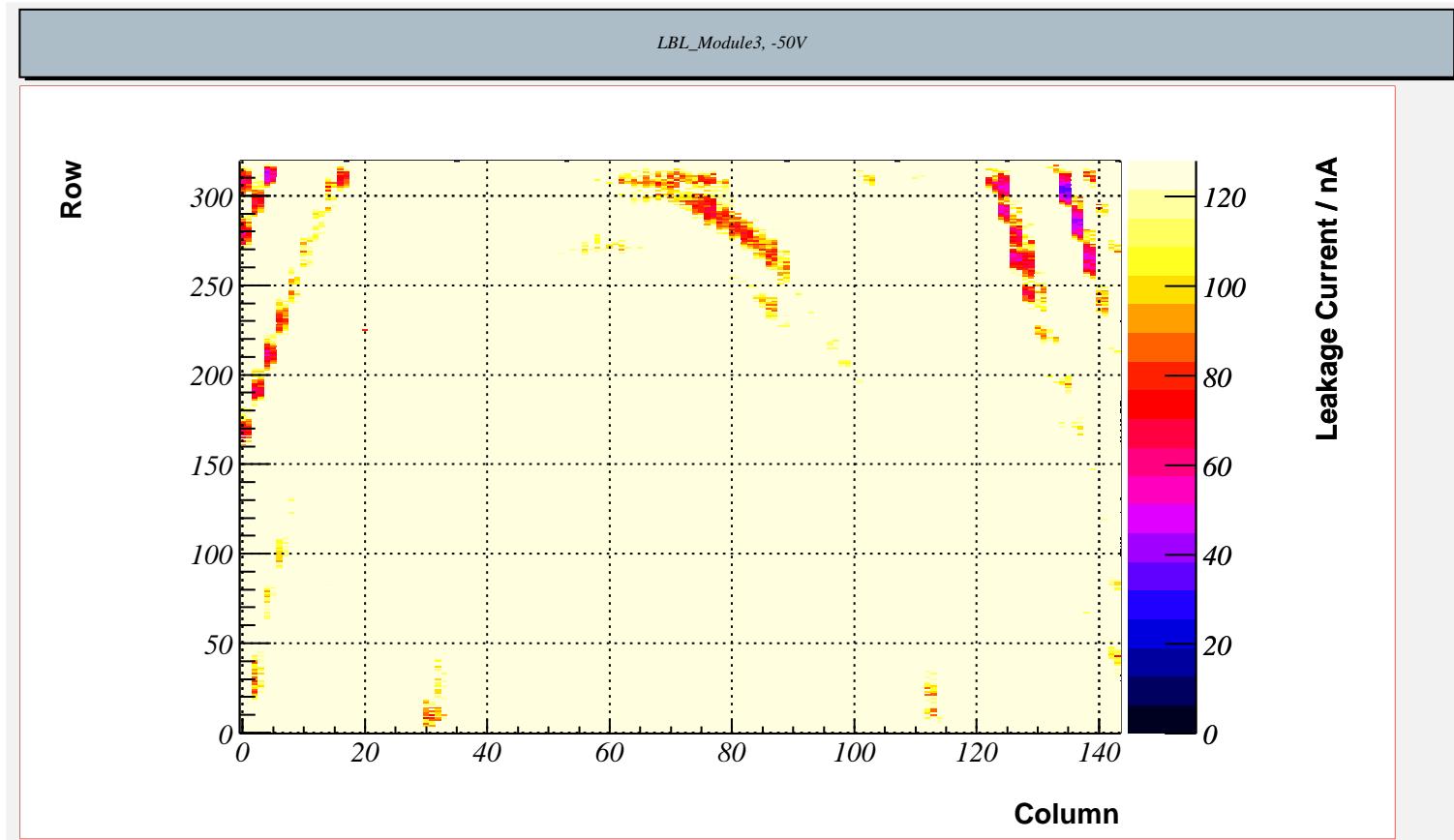
- Noise is strongly modulated in same manner, and some channels appear dead.

- Noise versus Leakage correlation at 60V bias for LBL_3 (IZM):



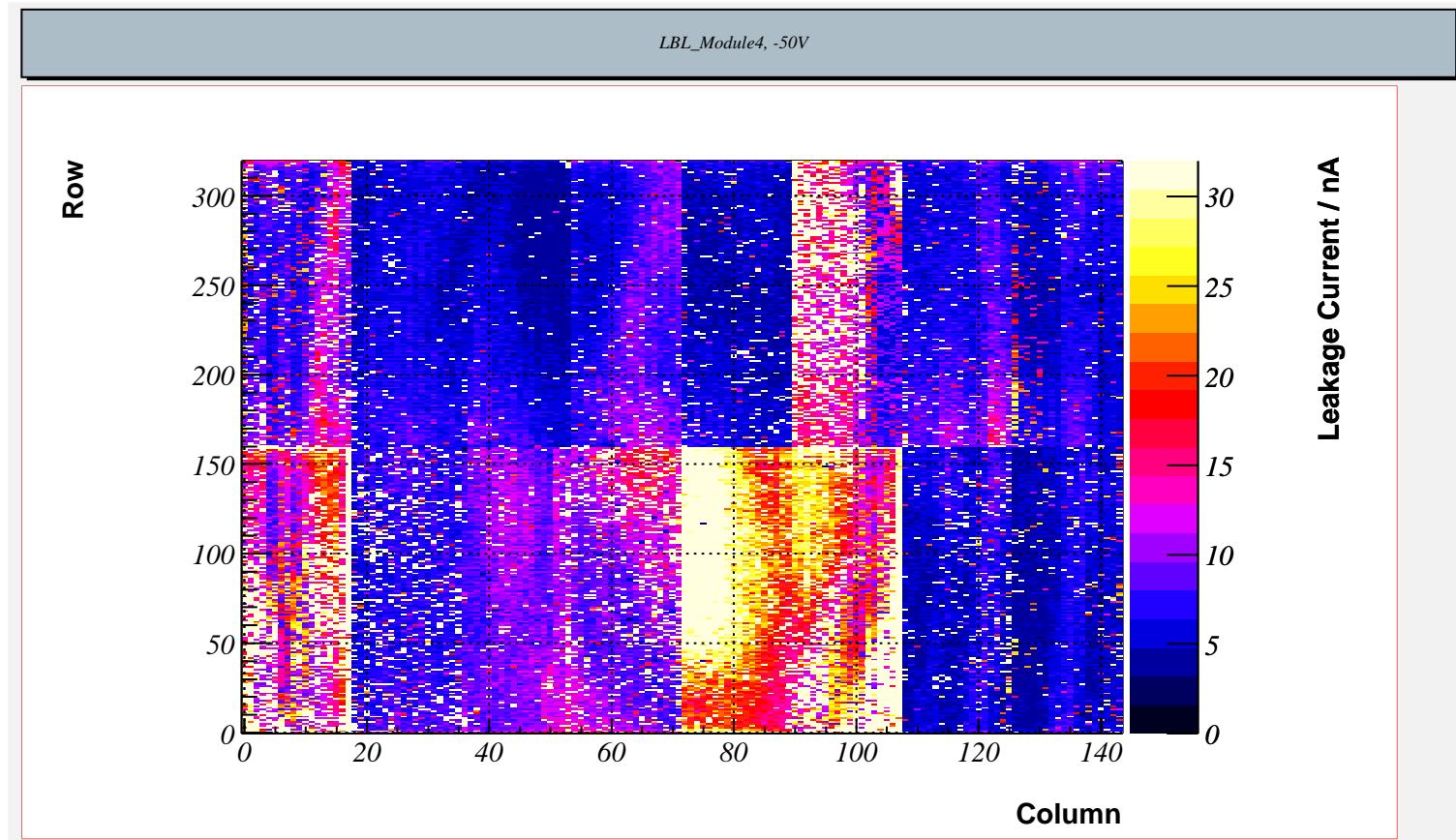
- Noise and leakage current are strongly correlated with expected slope.

- Leakage Current map at 50V bias for LBL_3 (IZM):



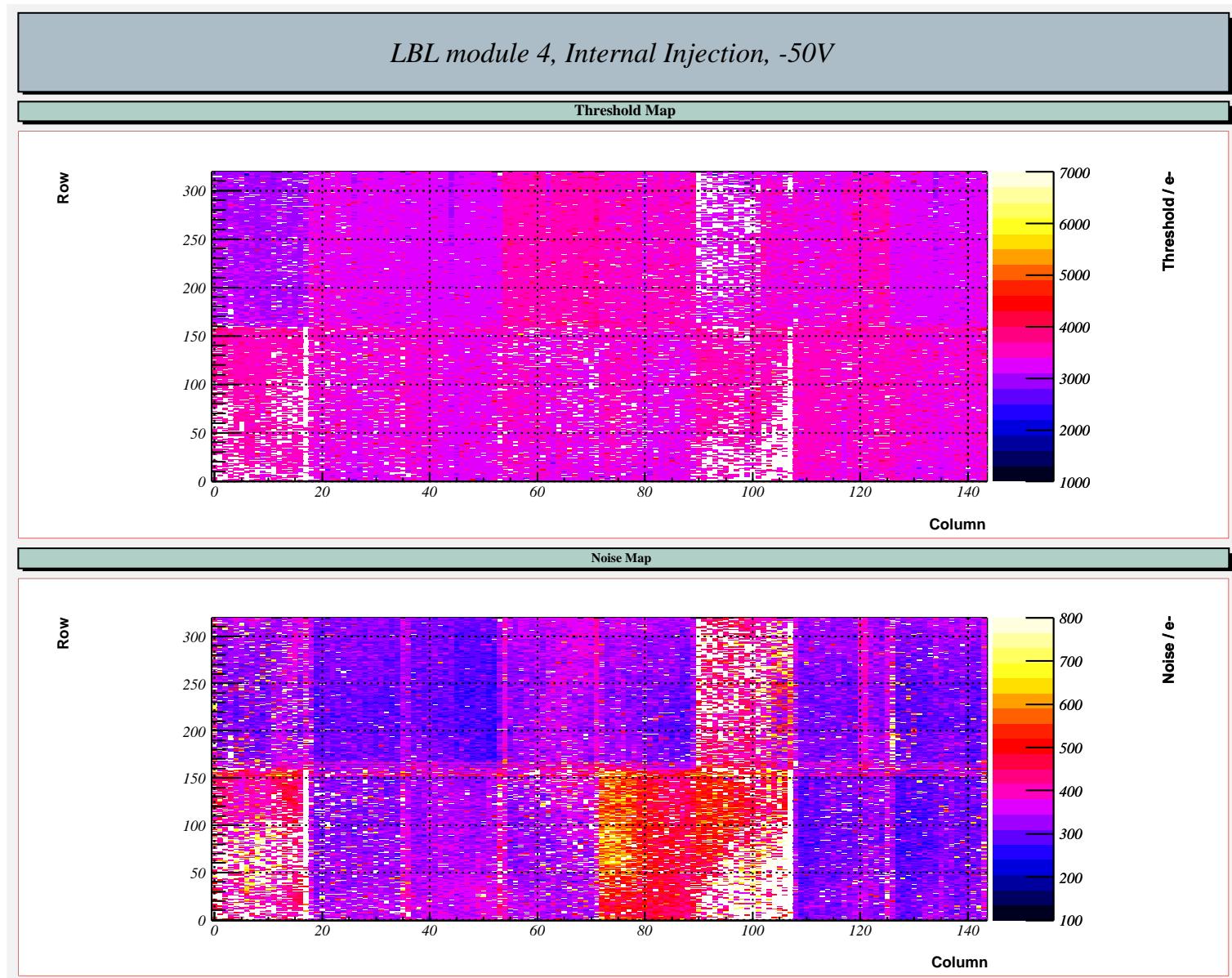
- Most pixels have leakage current above the saturation value of 128nA. In addition, almost every single pixel is dead for a threshold scan.
- Note that the leakage current compensation in FE-I1 has a finite maximum value, beyond which the preamp stops working (can be controlled somewhat by IVDD2).
- This pattern of behavior is exactly what would be expected based on our understanding of the sensor and electronics.

- Leakage Current map at 50V bias for LBL_4 (AMS):



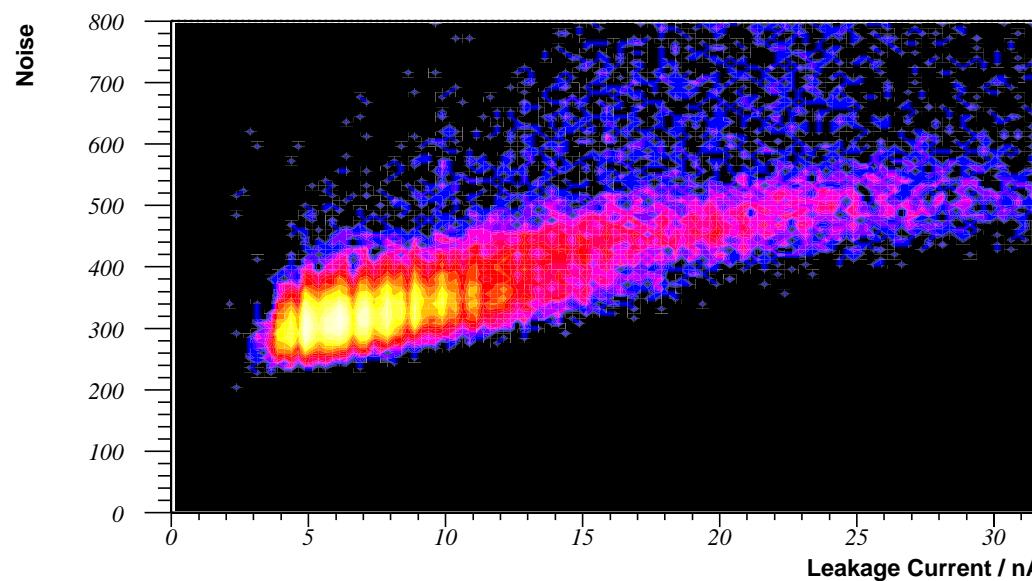
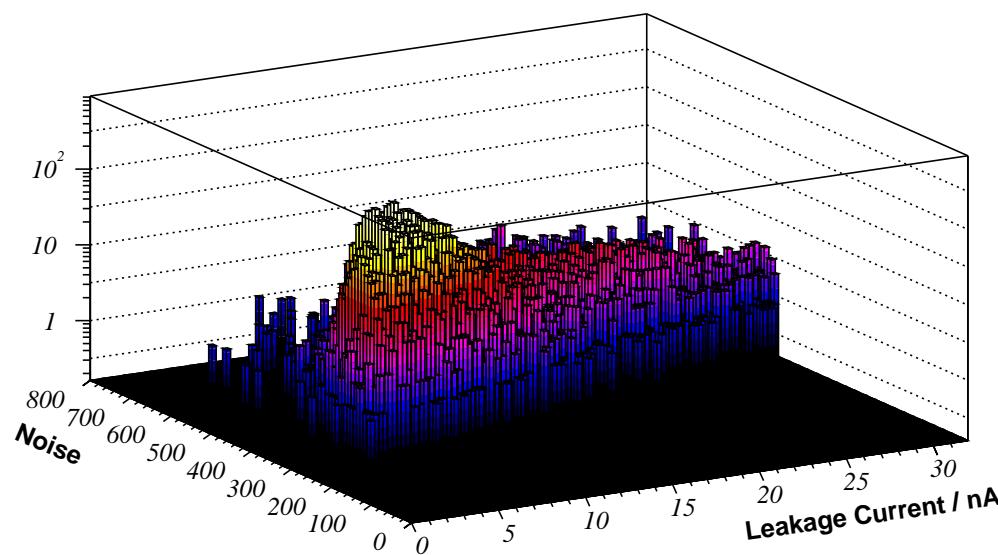
- Pattern is very different from IZM case. Leakage current variations are dominated by chip to chip variations. There are some underlying sensor modulations, but they are small.
- At this voltage, all IZM pixels are practically dead, and have leakage of 128nA or more. AMS bumps would need a resistance of more than $10\text{M}\Omega$ to avoid having the same leakage (pixel is at +1V compared to Guard).

- Threshold Map at 50V bias for LBL_4 (AMS):



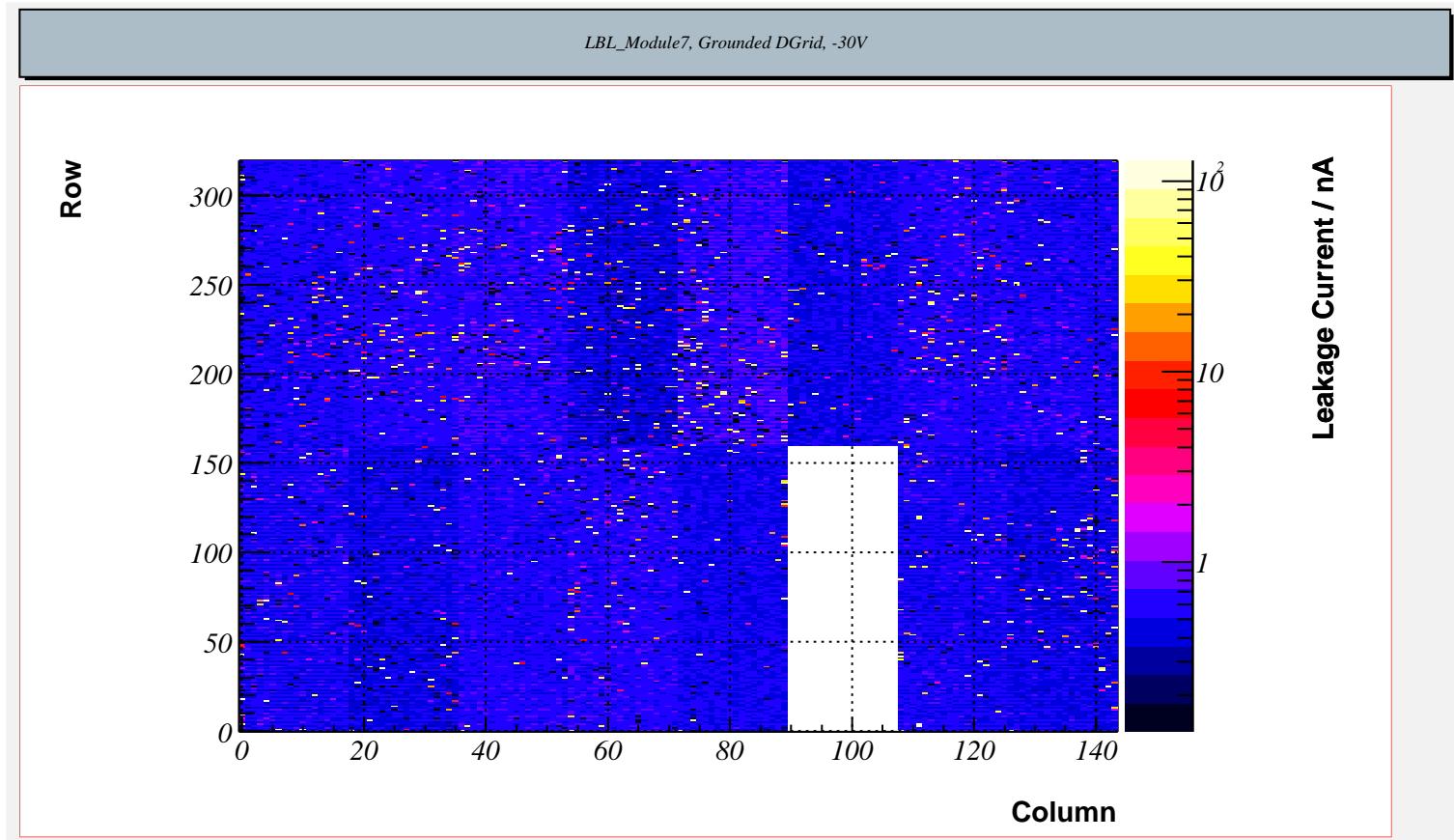
- Noise performance varies significantly from chip to chip.

- Noise versus Leakage correlation at 50V bias for LBL_4 (AMS):



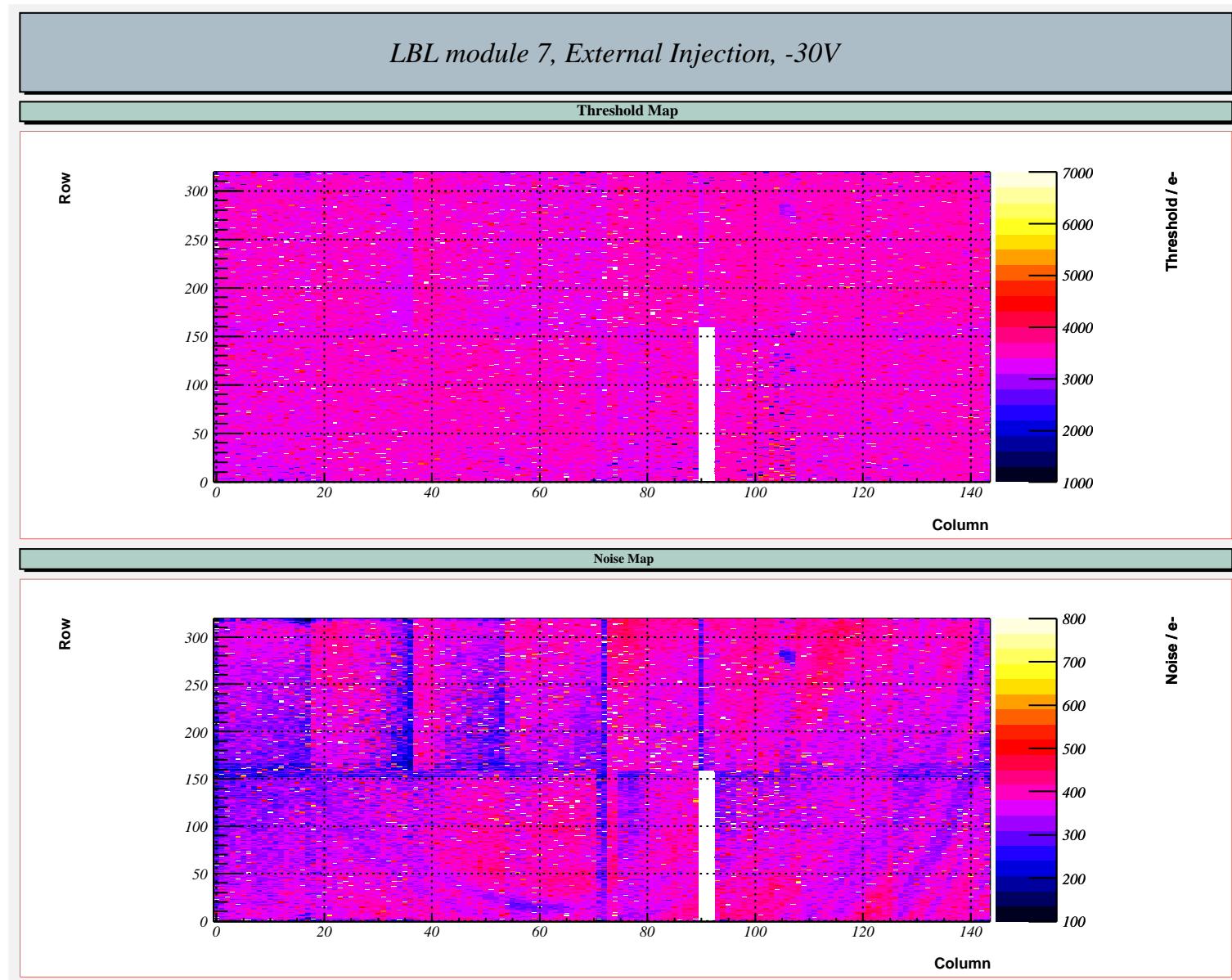
- Noise and leakage are not correlated as strongly as expected for real leakage.

- Leakage Current map at 30V bias for LBL_7 (AMS):



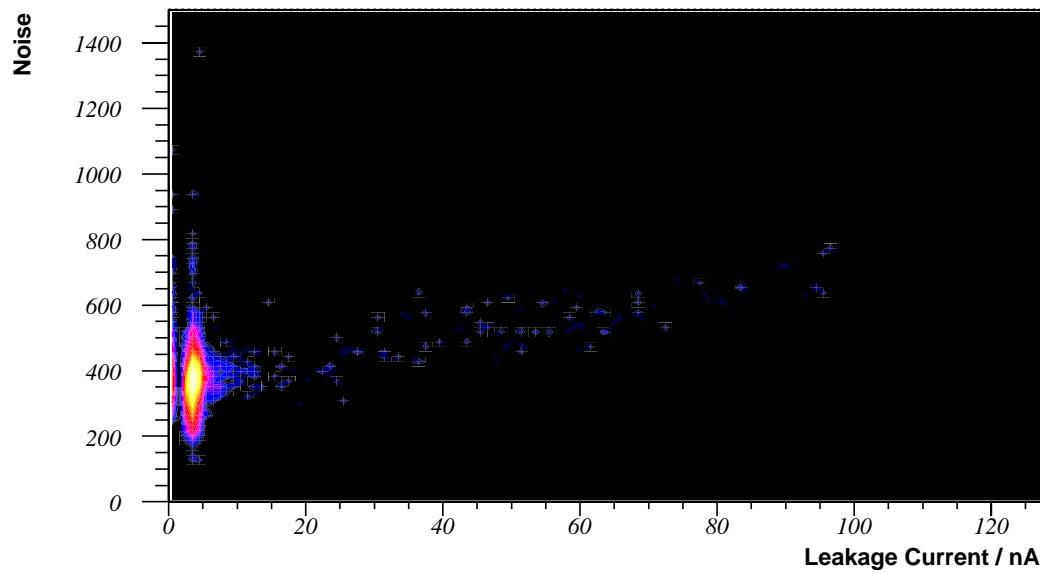
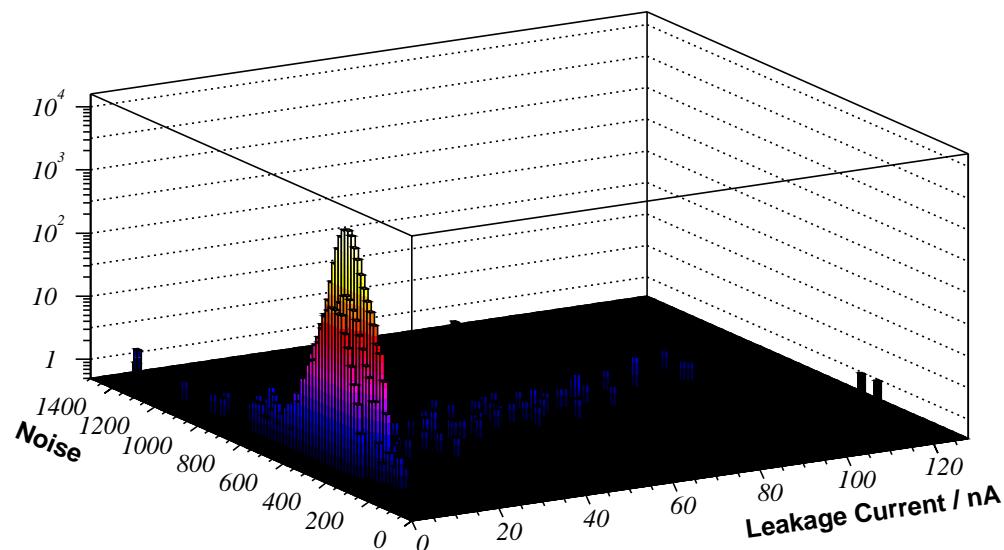
- Essentially no pattern seen in the leakage, well below the depletion voltage.
- Random speckling of bumps with high leakage, all others have almost nominal fully depleted value.
- For some reason, this module has a more uniformly high “resistive” behavior than LBL_4.

- Threshold Map at 30V bias for LBL_7 (AMS):



- Noise performance shows some wafer level variation, although leakage did not.

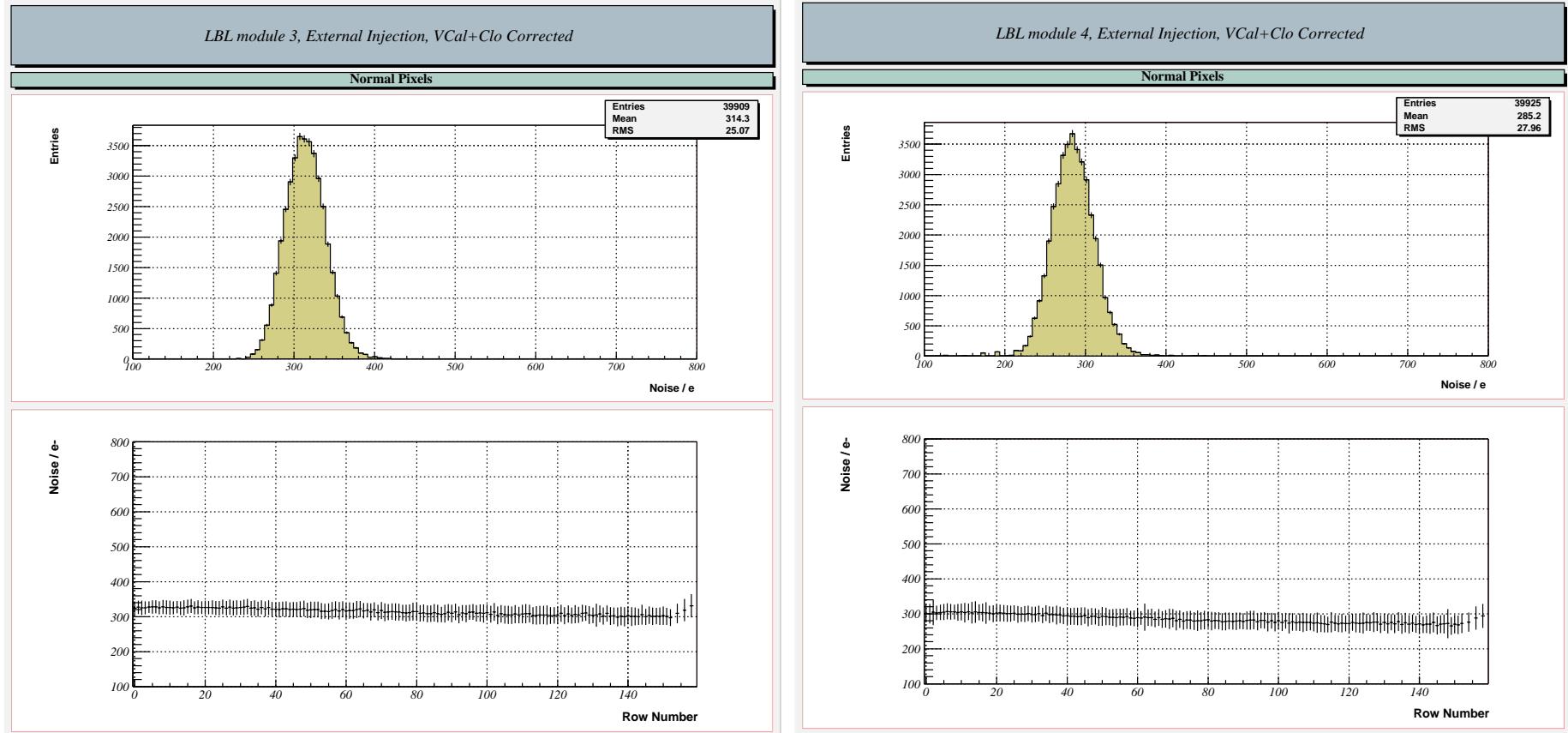
- Noise versus Leakage correlation at 30V bias for LBL_7 (AMS):



- Noise and leakage are not correlated as strongly as expected for real leakage.

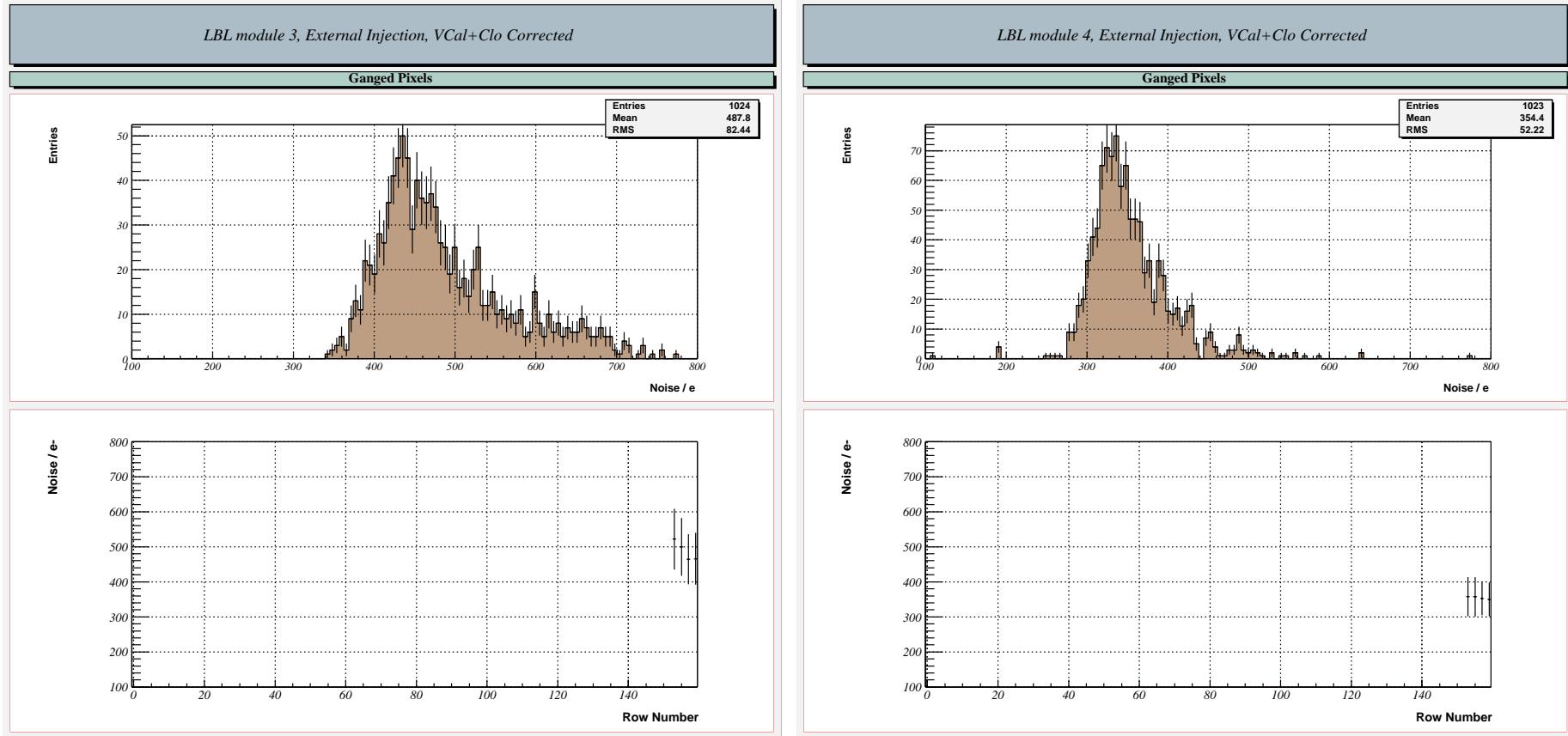
Noise Behavior of Different Pixel Types

- Compare noise behavior for normal pixels in LBL_3 (IZM) and LBL_4 (AMS):



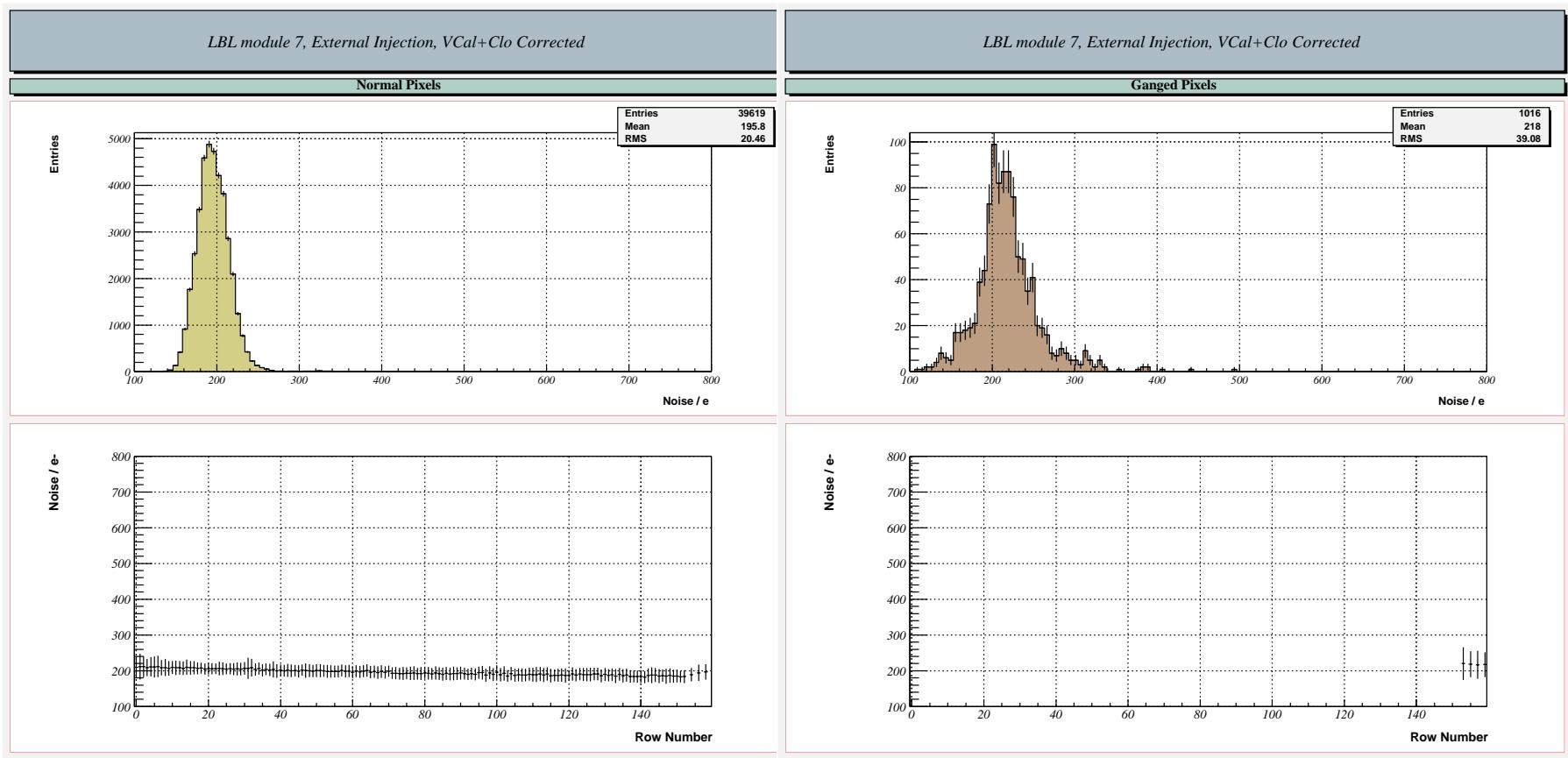
- Note that LBL_3 is an A-chip module, while LBL_4 is a B_chip module.
- Basically, the noise for normal pixels is very similar.

- Compare noise behavior for ganged pixels in LBL_3 (IZM) and LBL_4 (AMS):



- In this case, the noise behavior is very different. The ganged pixels have much lower noise in the AMS module, and they show a reduced dependence on row number (meaning presumably capacitance).
- The noise seems to be almost independent of the sensor capacitance, as though it was being partially screened by the large bump resistance.

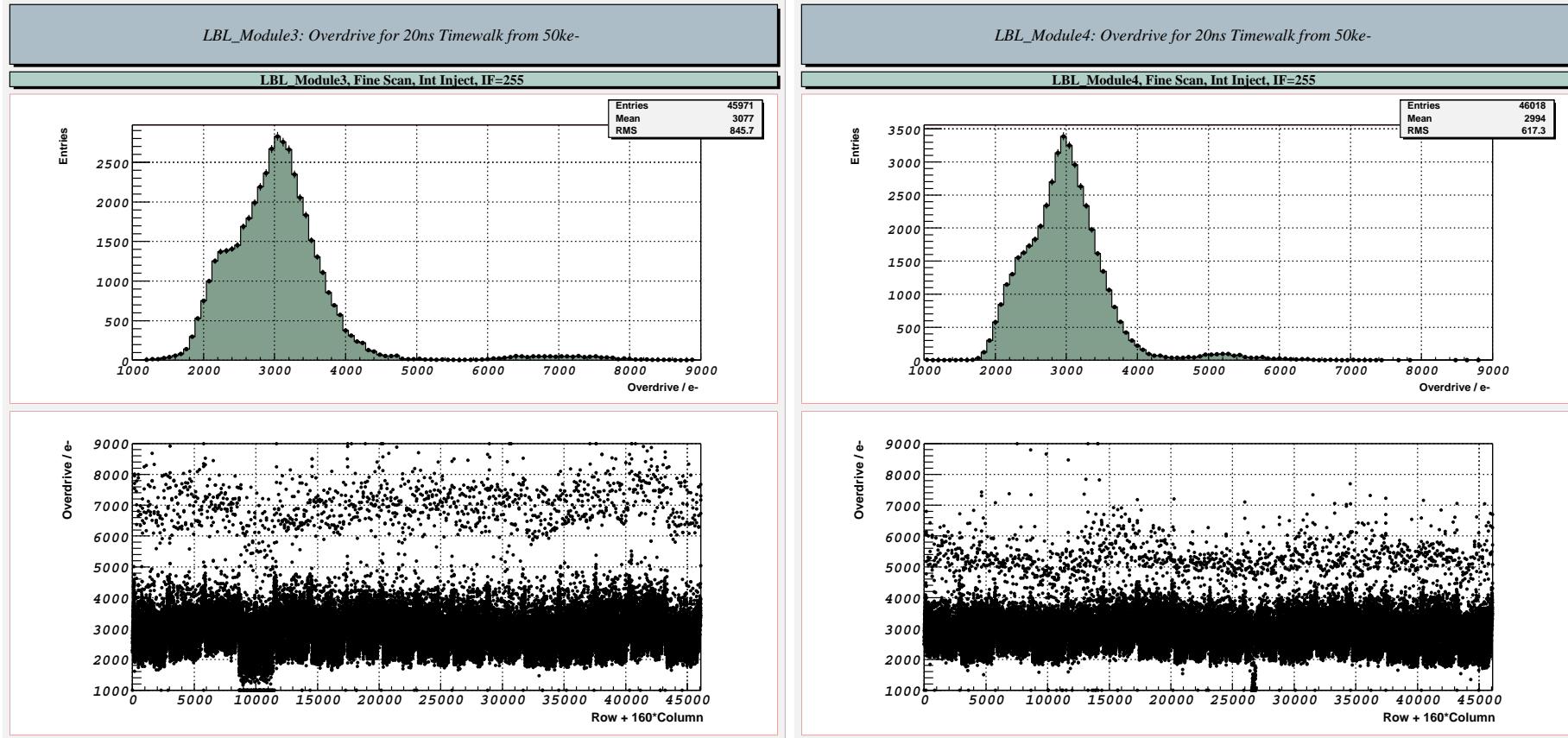
- Compare noise behavior for pixels in LBL_7 (AMS):



- Note this scan was done with new noise normalization (reduced by 1.4...)
- This module is even more extreme, with essentially no difference in average noise between normal and ganged pixels.
- Recall also that this AMS module showed even less leakage current at low VDet than LBL_4 did. This suggests the bump resistance is even higher than that of LBL_4.

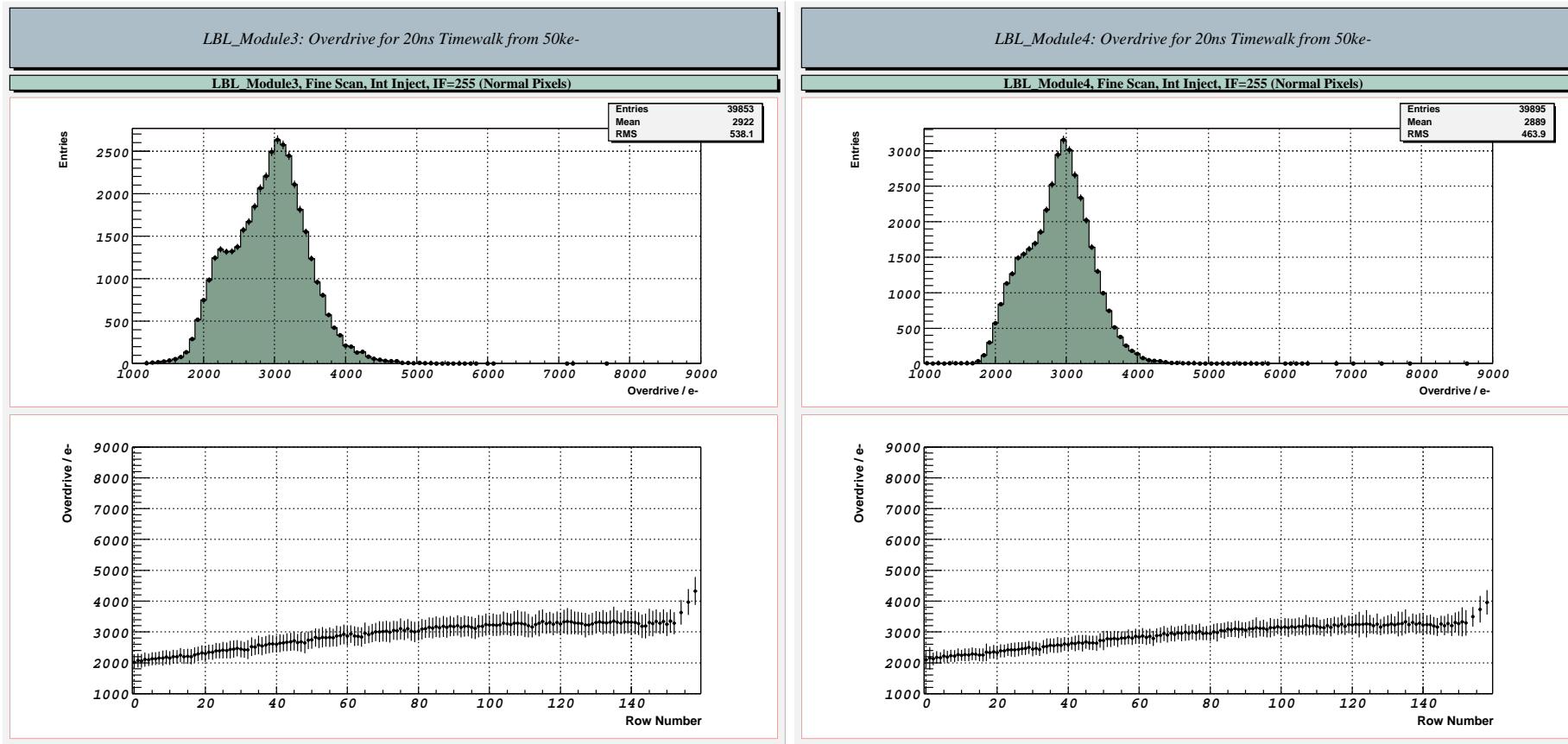
Timewalk Behavior for Different Pixel Types

- Compare results of timewalk scans for LBL_3 (IZM) and LBL_4 (AMS):



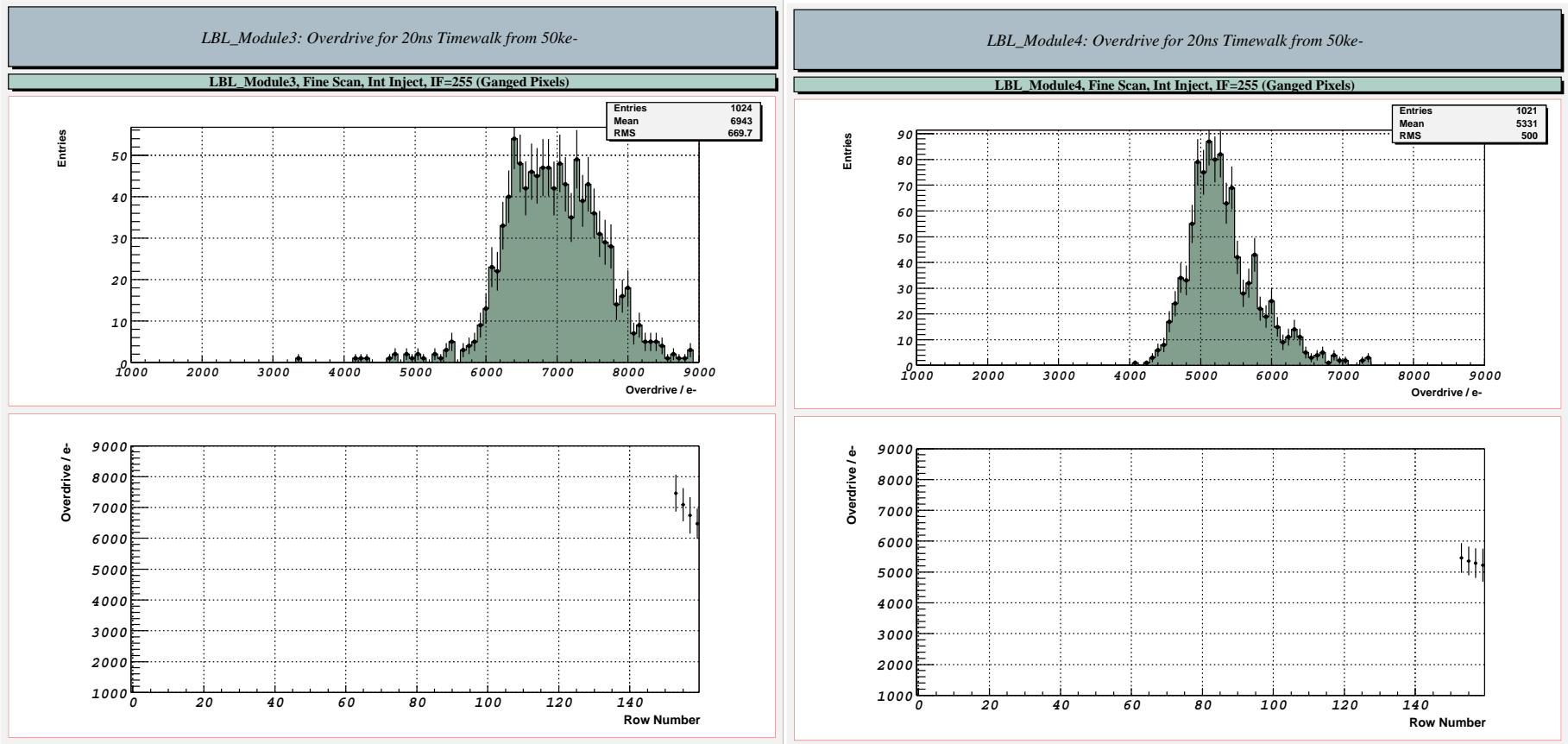
- Can see that the timewalk (overdrive) for the normal pixels is similar, but the timewalk for the ganged pixels is very different.
- This is despite the expectation that A chips used in LBL_3 should have slightly better timewalk performance.

- Compare results of timewalk for normal pixels for LBL_3 (IZM) and LBL_4 (AMS):



- Timewalk performance in detail is quite similar for the normal pixels.

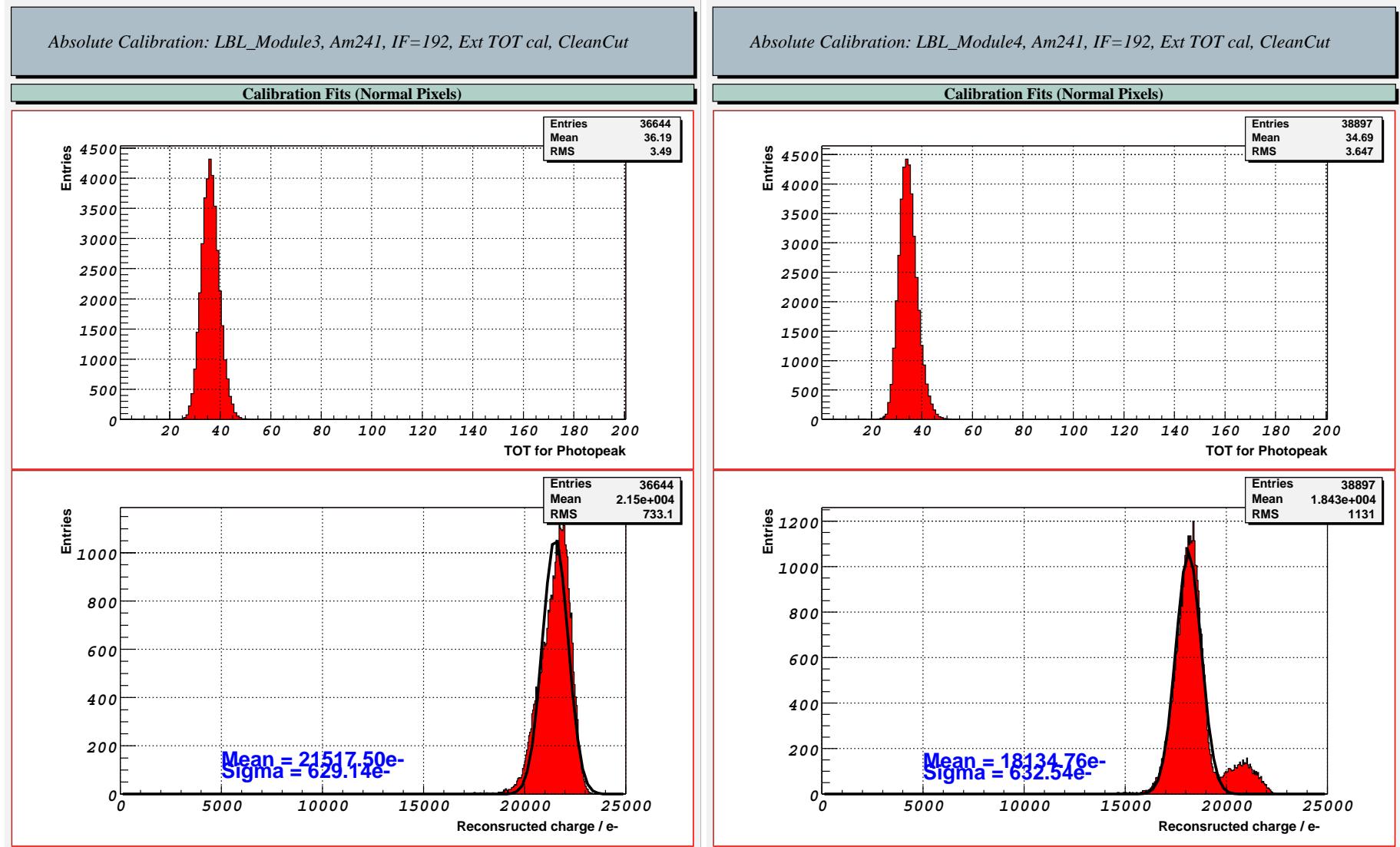
- Compare results of timewalk for ganged pixels for LBL_3 (IZM) and LBL_4 (AMS):



- Just as observed for the noise distribution, can see that the timewalk for the ganged AMS pixels is much less than for the ganged IZM pixels.
- In addition, the row number dependence is also much less for the AMS pixels, producing the narrower timewalk distribution seen above.

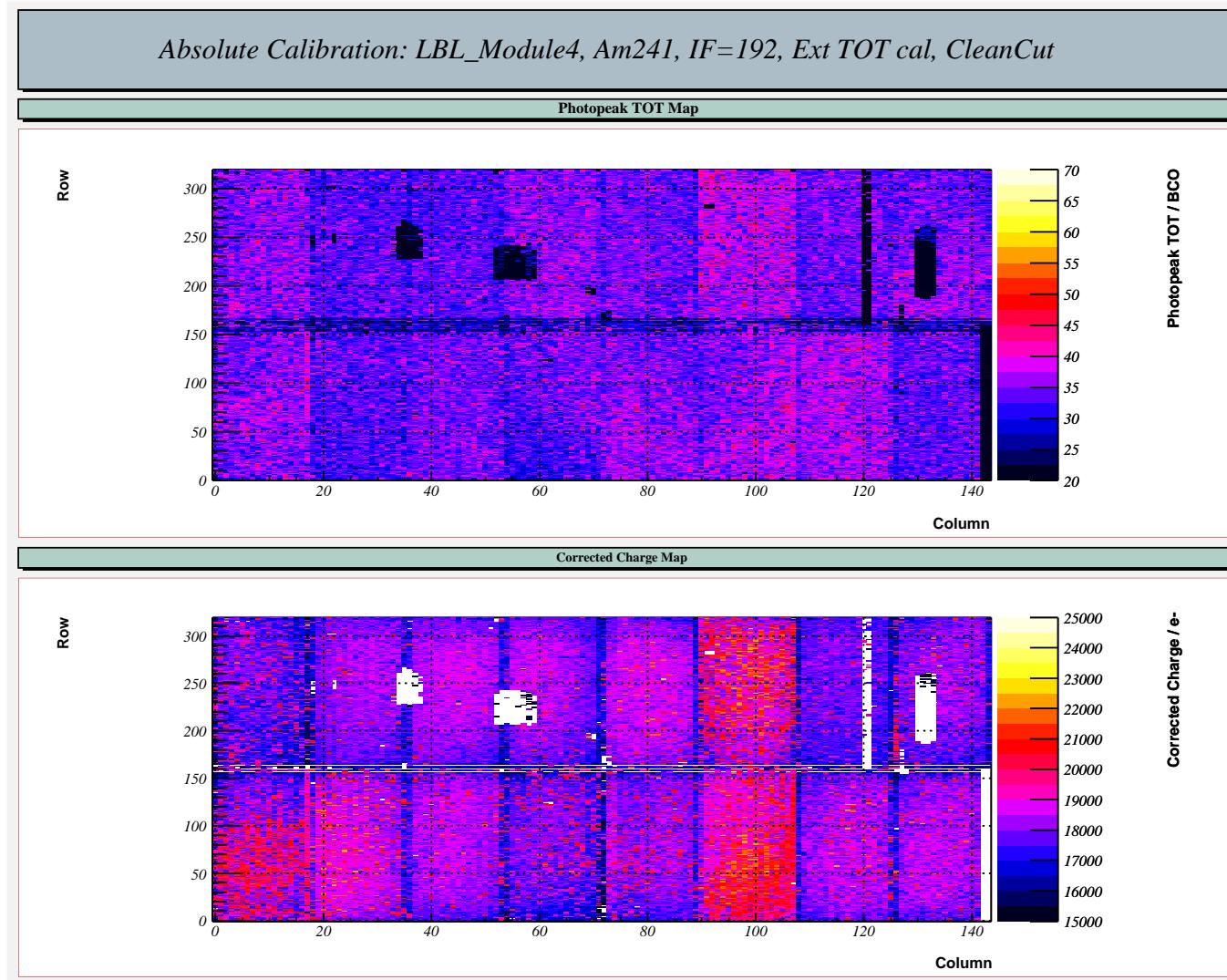
Absolute Calibration with Am241 Source

Compare source calibration for normal pixels in LBL_3 (IZM) and LBL_4 (AMS):



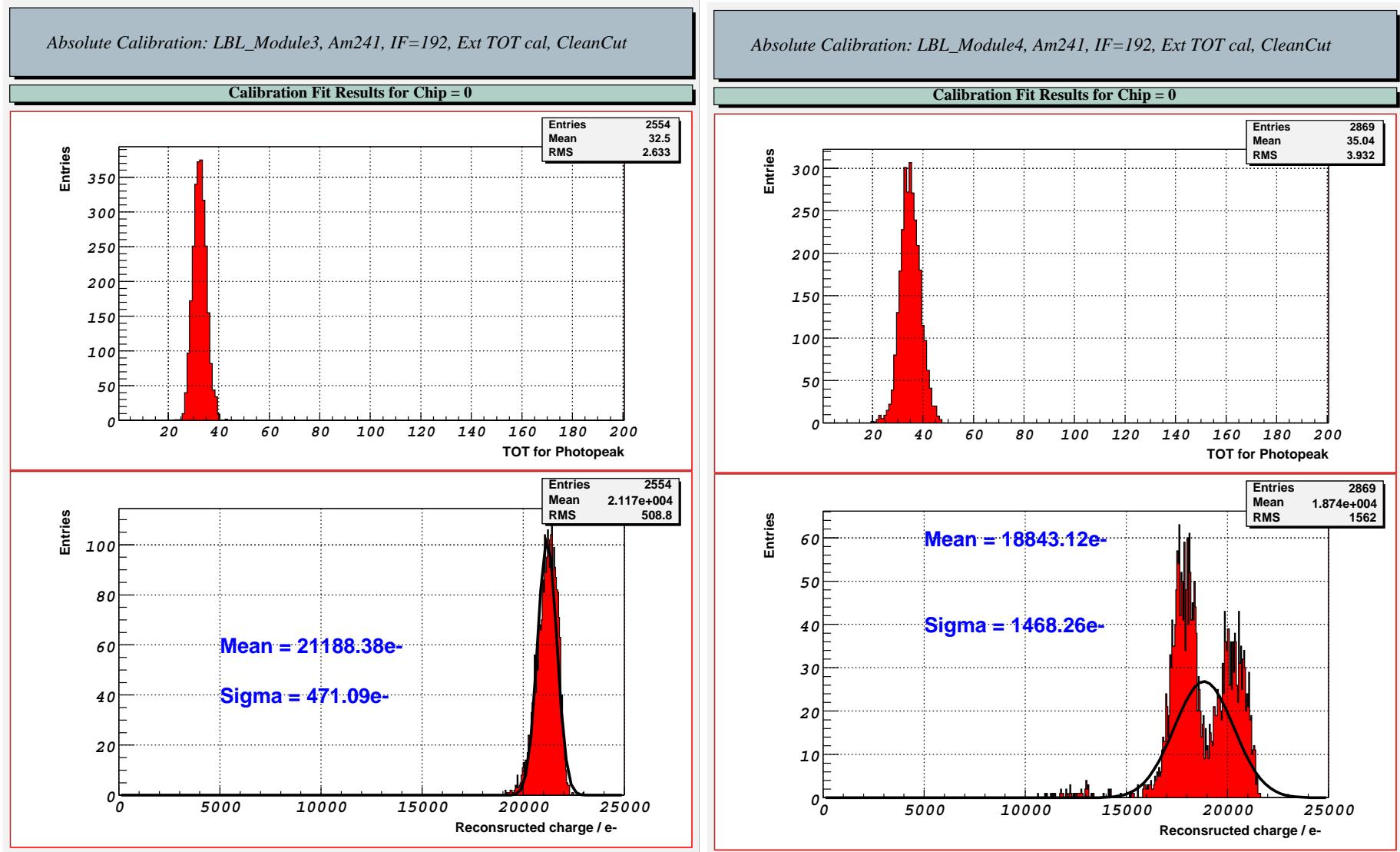
- Similar TOT distributions, but rather different charges, and double peak in LBL_4.

- Map of calibration results for LBL_4 (AMS) Upper plot is TOT, lower is charge:



- Higher charge peak comes from chips 0, 5, and 10. Recall these were the same chips which also showed significant leakage current below depletion, suggesting their bump resistances are lower.

- Compare Chip 0 on LBL_3 (IZM) and LBL_4 (AMS):

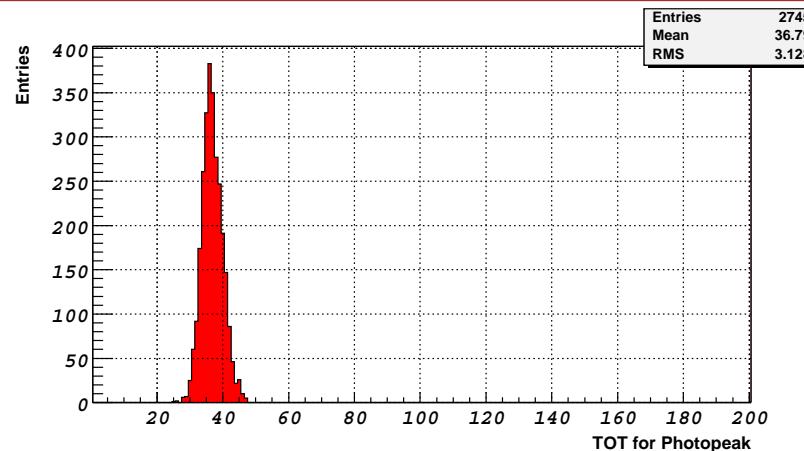


- Many pixels in LBL_4 (AMS) agree with the narrower peak seen in LBL_3 (IZM).
The regions with similar charge are the regions which appeared also in the leakage map with higher leakage below depletion.

- Compare Chip 13 on LBL_3 (IZM) and LBL_4 (AMS):

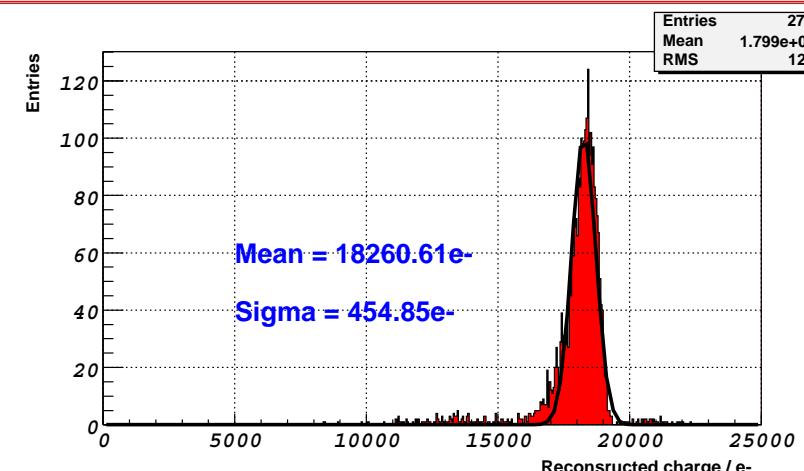
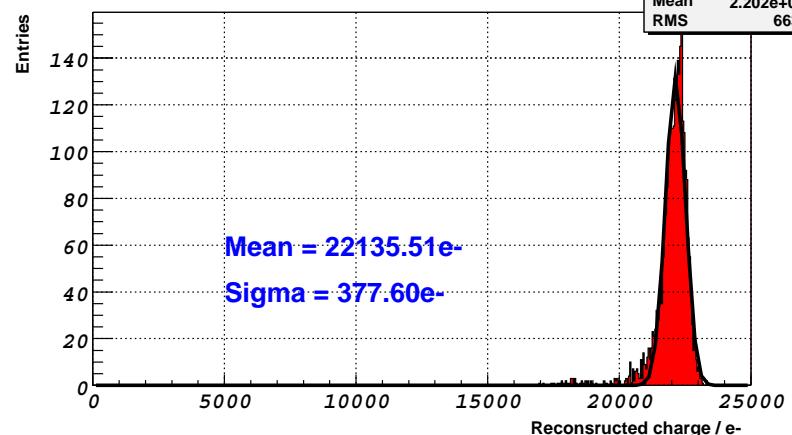
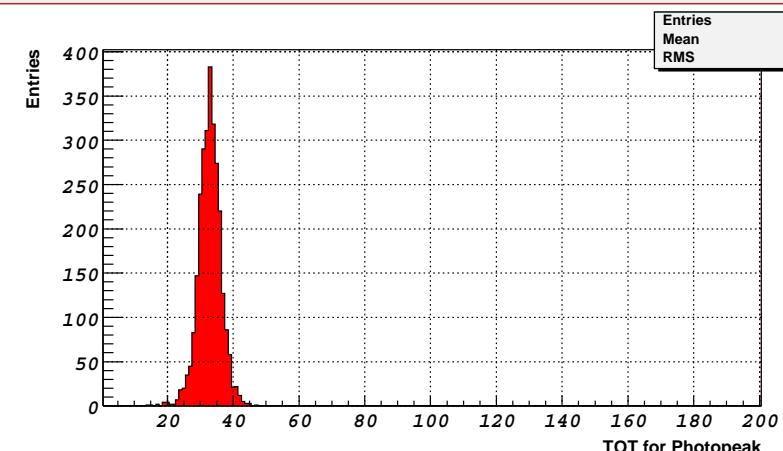
Absolute Calibration: LBL_Module3, Am24I, IF=192, Ext TOT cal, CleanCut

Calibration Fit Results for Chip = 13



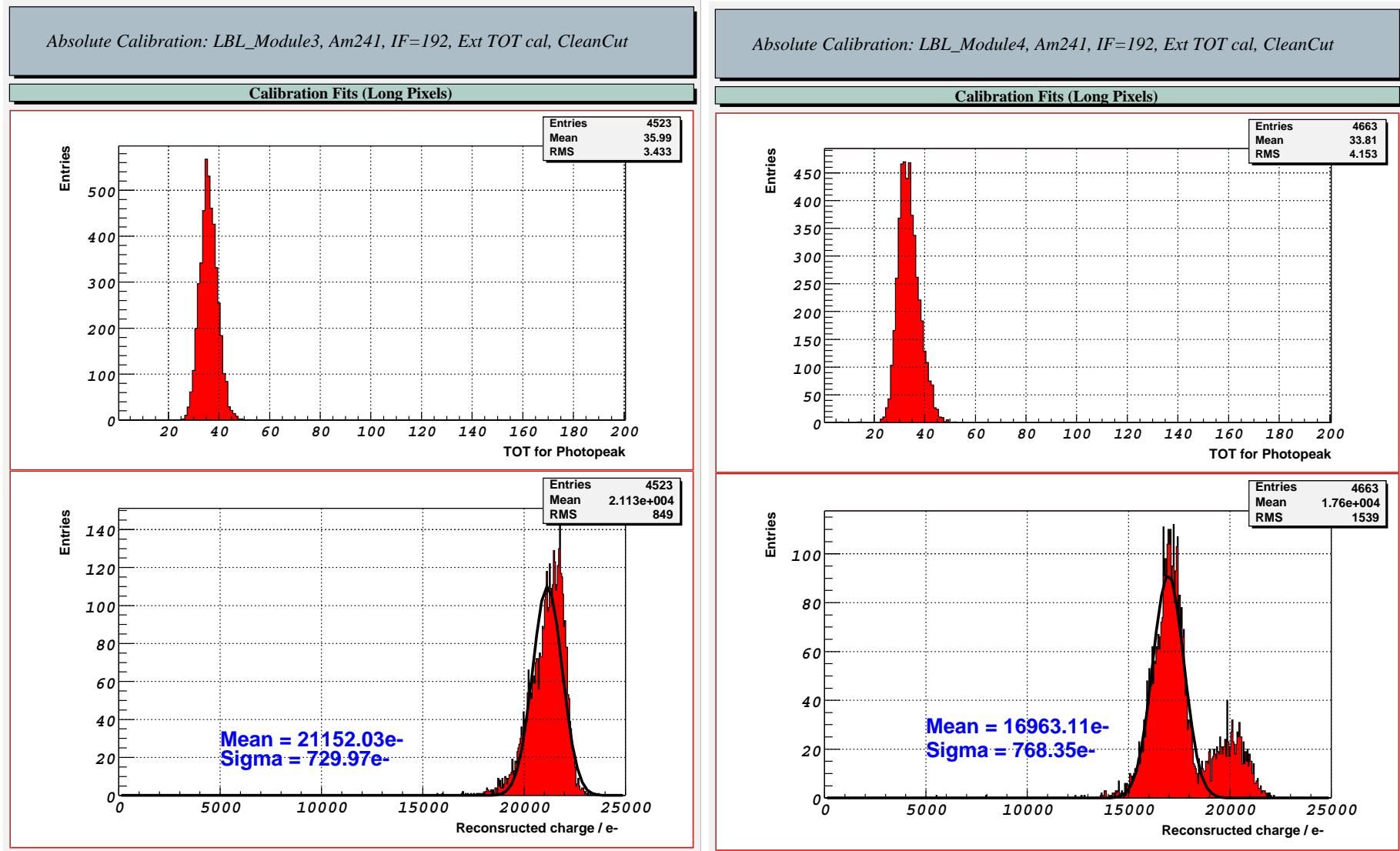
Absolute Calibration: LBL_Module4, Am24I, IF=192, Ext TOT cal, CleanCut

Calibration Fit Results for Chip = 13



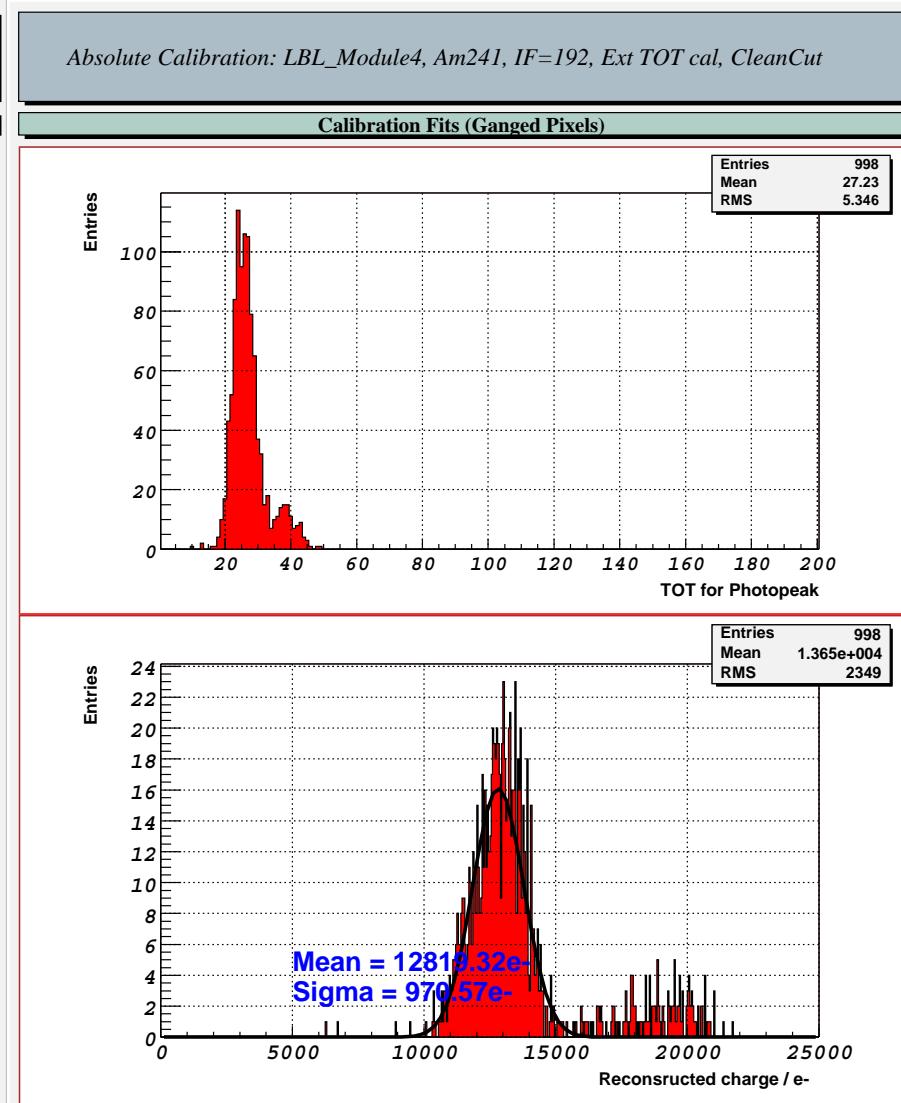
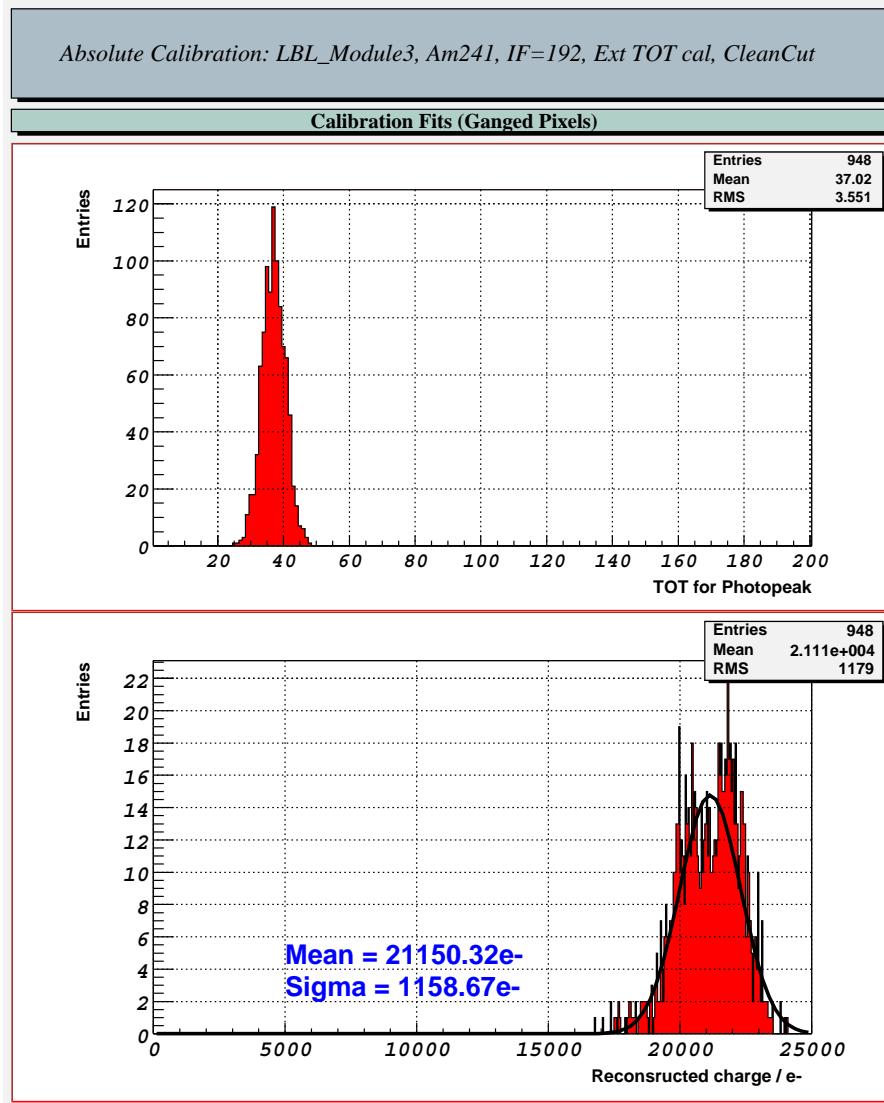
- Chip 13 on LBL_4 (AMS) had low leakage everywhere when below depletion voltage. Most pixels in this chip in LBL_4 (AMS) reconstruct a much lower charge than seen in LBL_3 (IZM).

- Compare long pixels on LBL_3 (IZM) and LBL_4 (AMS):



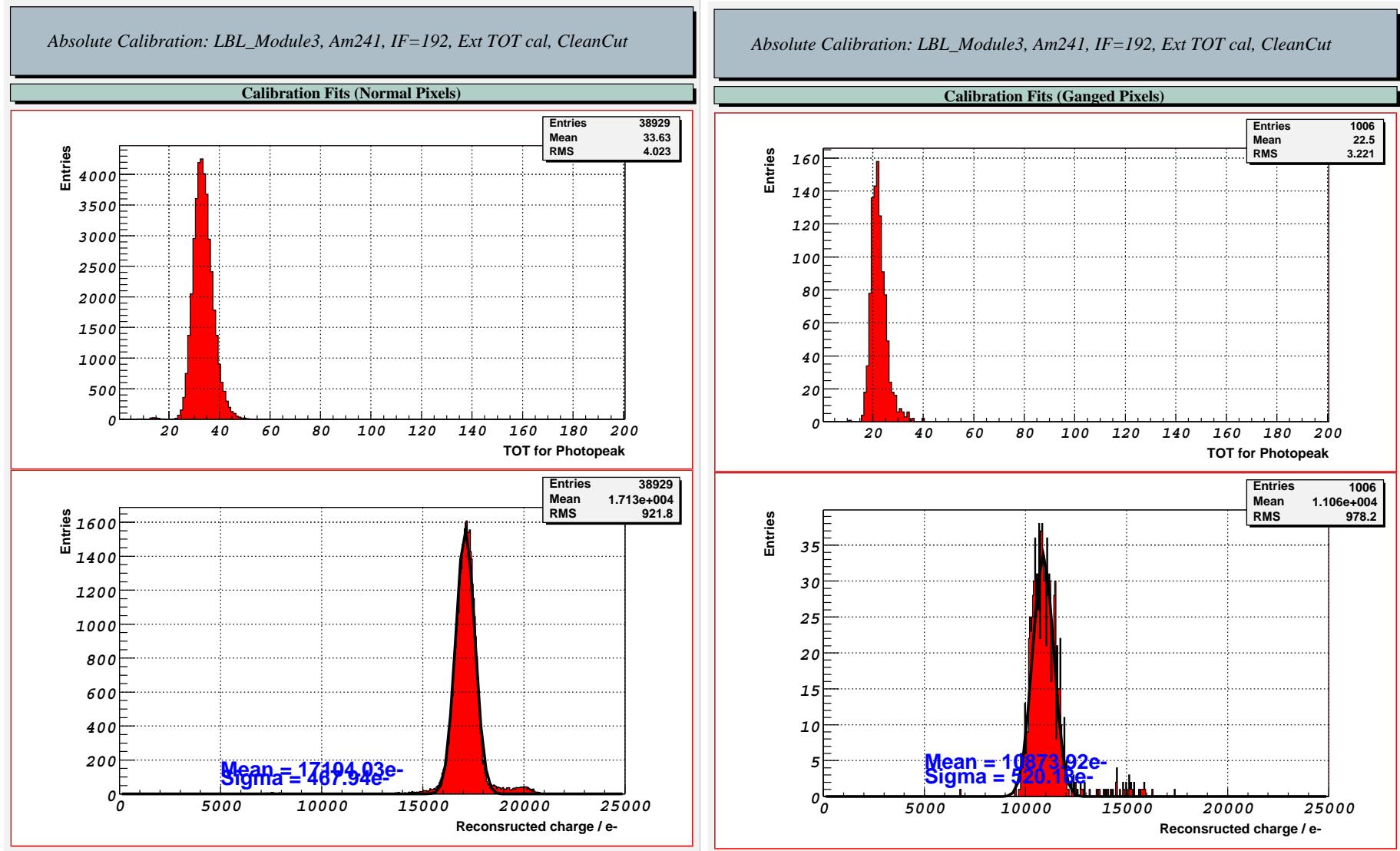
- The long pixels in LBL_3 (IZM) have the same charge as the normal pixels. The long pixels in LBL_4 (AMS) have about 1000e less charge than the normal pixels.

- Compare ganged pixels on LBL_3 (IZM) and LBL_4 (AMS):



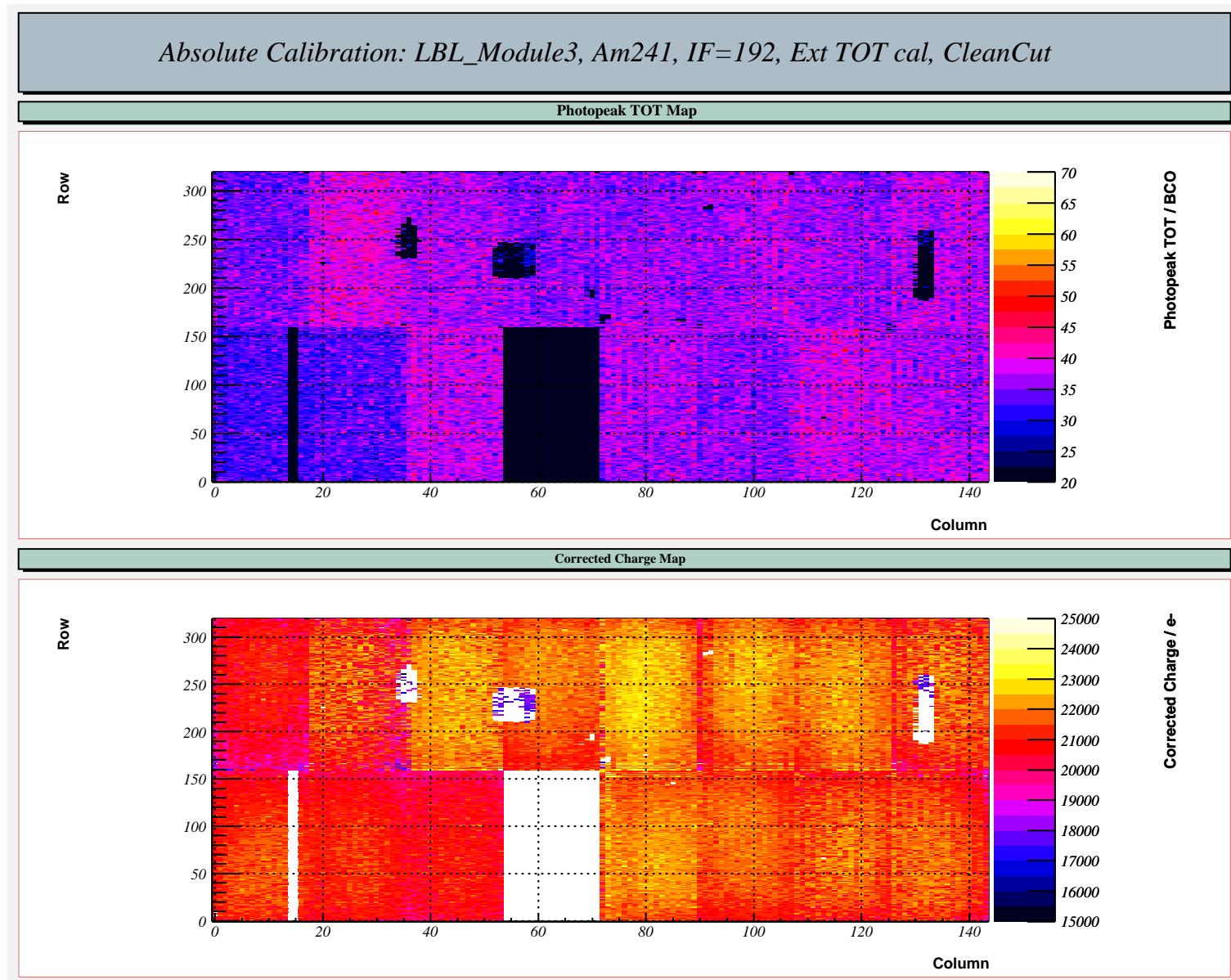
- Although the distributions are broader, LBL_3 has similar charge in the ganged and normal pixels. LBL_4 has substantially lower charge in the ganged pixels (and also lower TOT compared to the normal pixels). This suggests large charge losses.

- Compare normal and ganged pixels in LBL_7 (AMS):

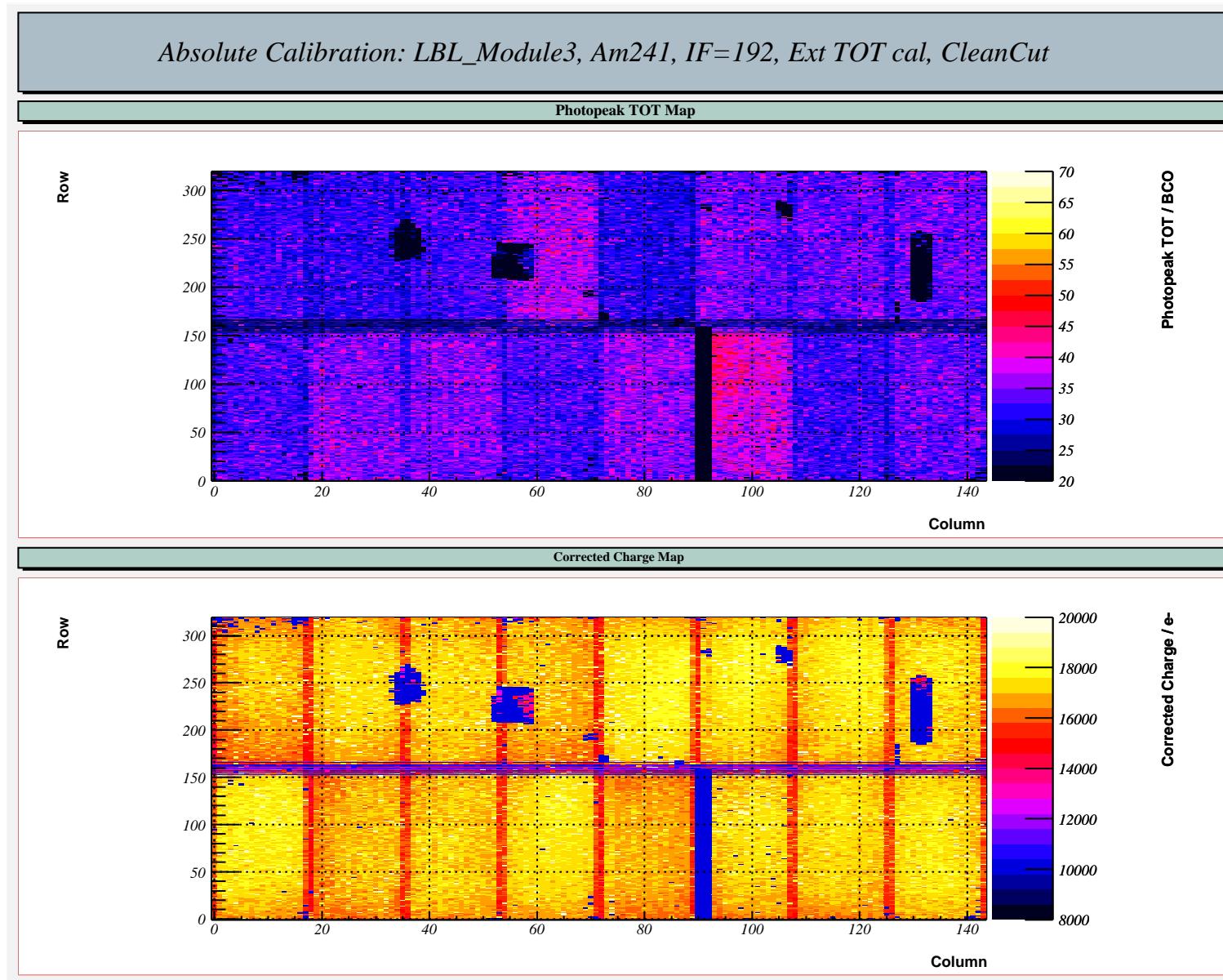


- LBL_7 shows very uniform charge response, much lower than LBL_3, but comparable to the low regions of LBL_4. This corresponds to the leakage behavior below depletion. LBL_7 also shows much lower charge in the ganged pixels.

- Charge map for LBL_3 (IZM) shows uniform response for all types of pixels:



- Charge map for LBL_7 (AMS) shows non-uniform response for different types of pixels:

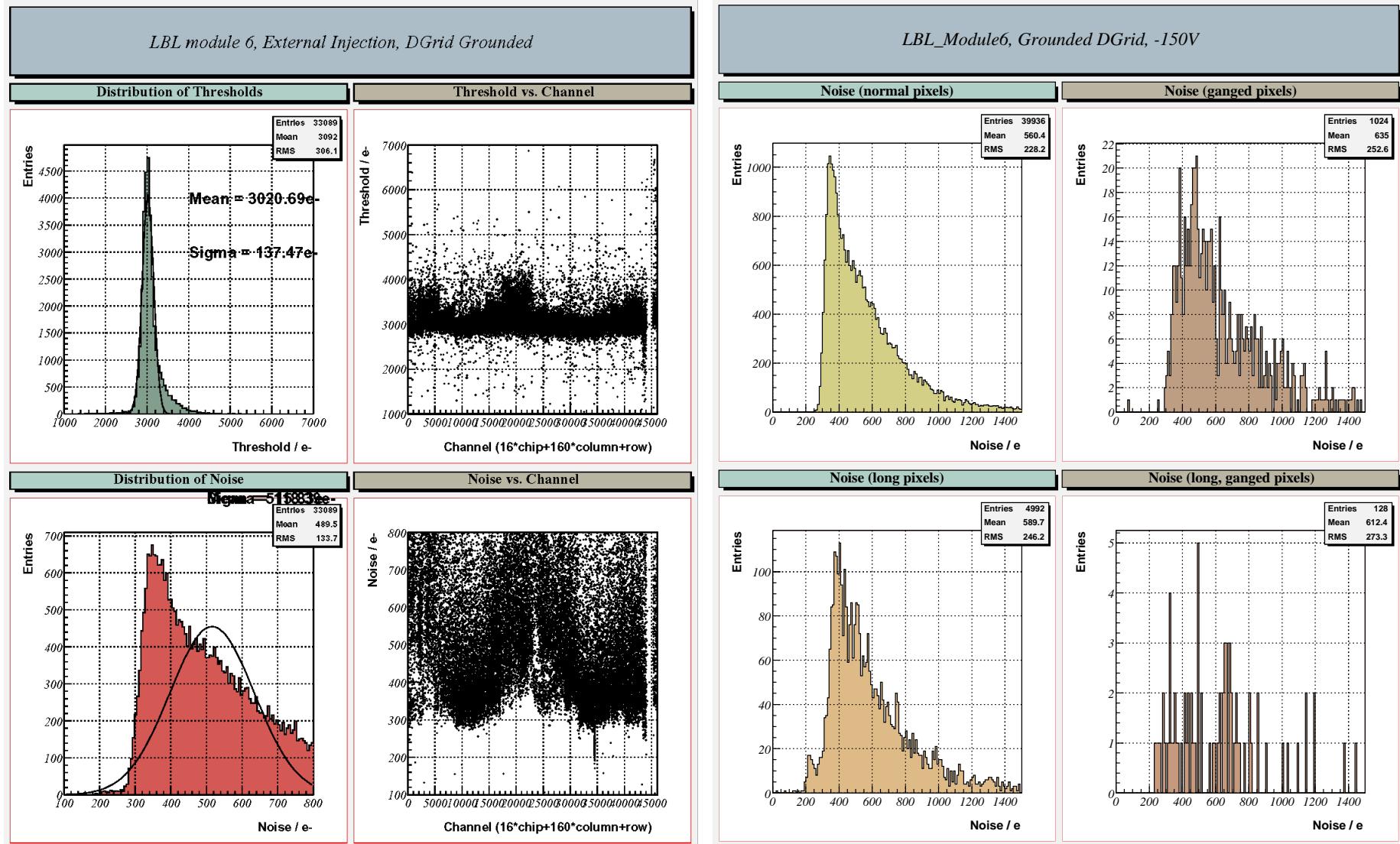


Summary of AMS versus IZM

- Observe very different behavior of noise and leakage current when the sensor is just below the depletion voltage. IZM bumps behave with a consistent low resistance. AMS bumps behave with a somewhat variable, and apparently very high resistance.
- Observe similar noise and timewalk behavior for normal pixels in AMS and IZM modules. However, behavior of ganged pixels is very different. AMS modules appear to show a screening of the high capacitance of the different special pixels. This results in lower noise and timewalk for the ganged pixels than in IZM modules.
- One IZM module shows a consistent, albeit high, response to an Am241 source. AMS modules show a significantly lower response in those regions which appear to have the most resistive bumps (low leakage when below depletion). In some regions of one AMS module, there appear to be bumps which show similar behavior to IZM bumps (high leakage and noise below depletion, and similar charge response).
- The IZM module shows a uniform charge response for all types of pixels. Two different AMS modules both show significantly lower charge response for the long and ganged pixels, compared to the normal pixels. The charge loss is roughly 30%.

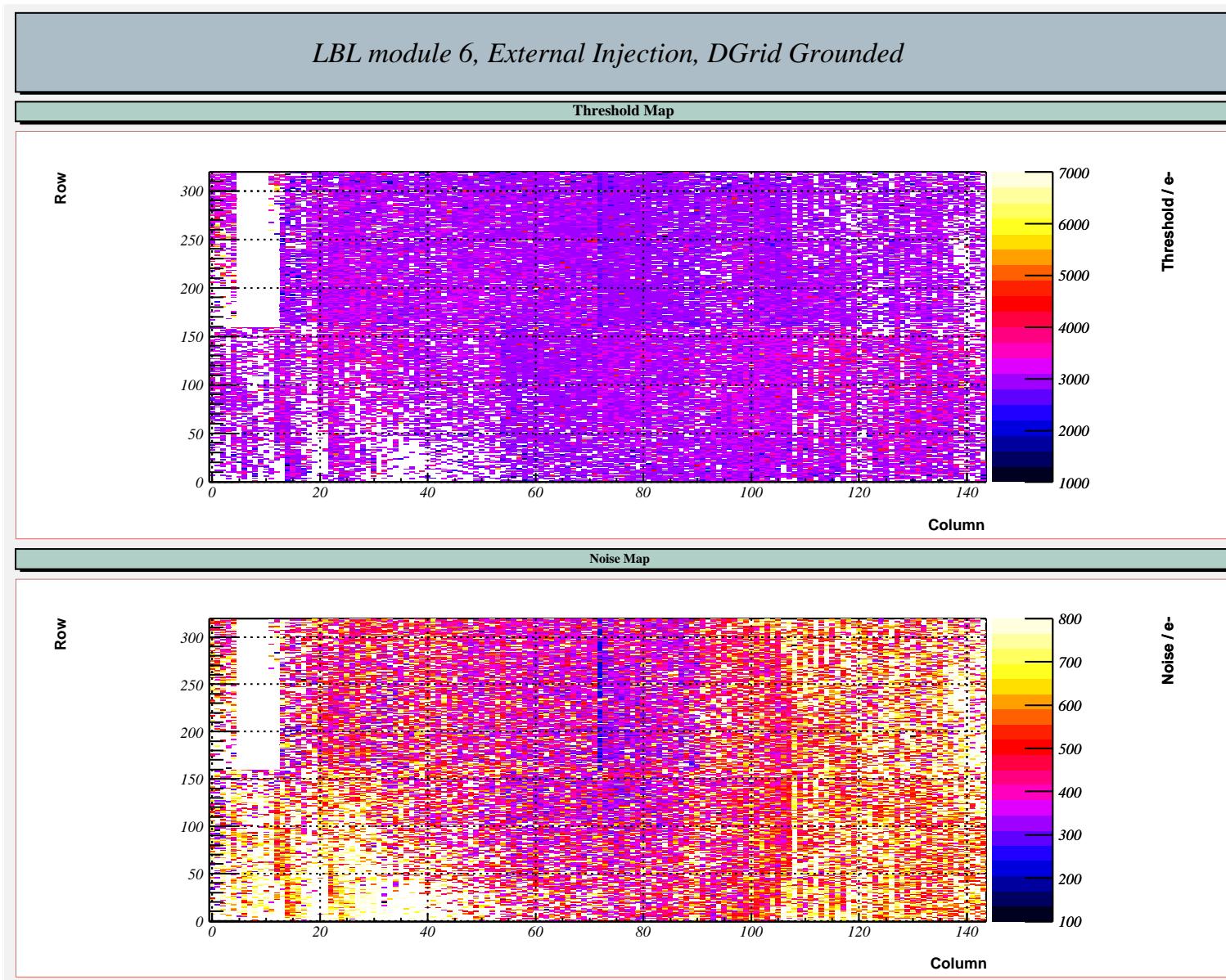
Results of first Tesla module

- The LBL_6 module was very noisy. After threshold tune, found the following:



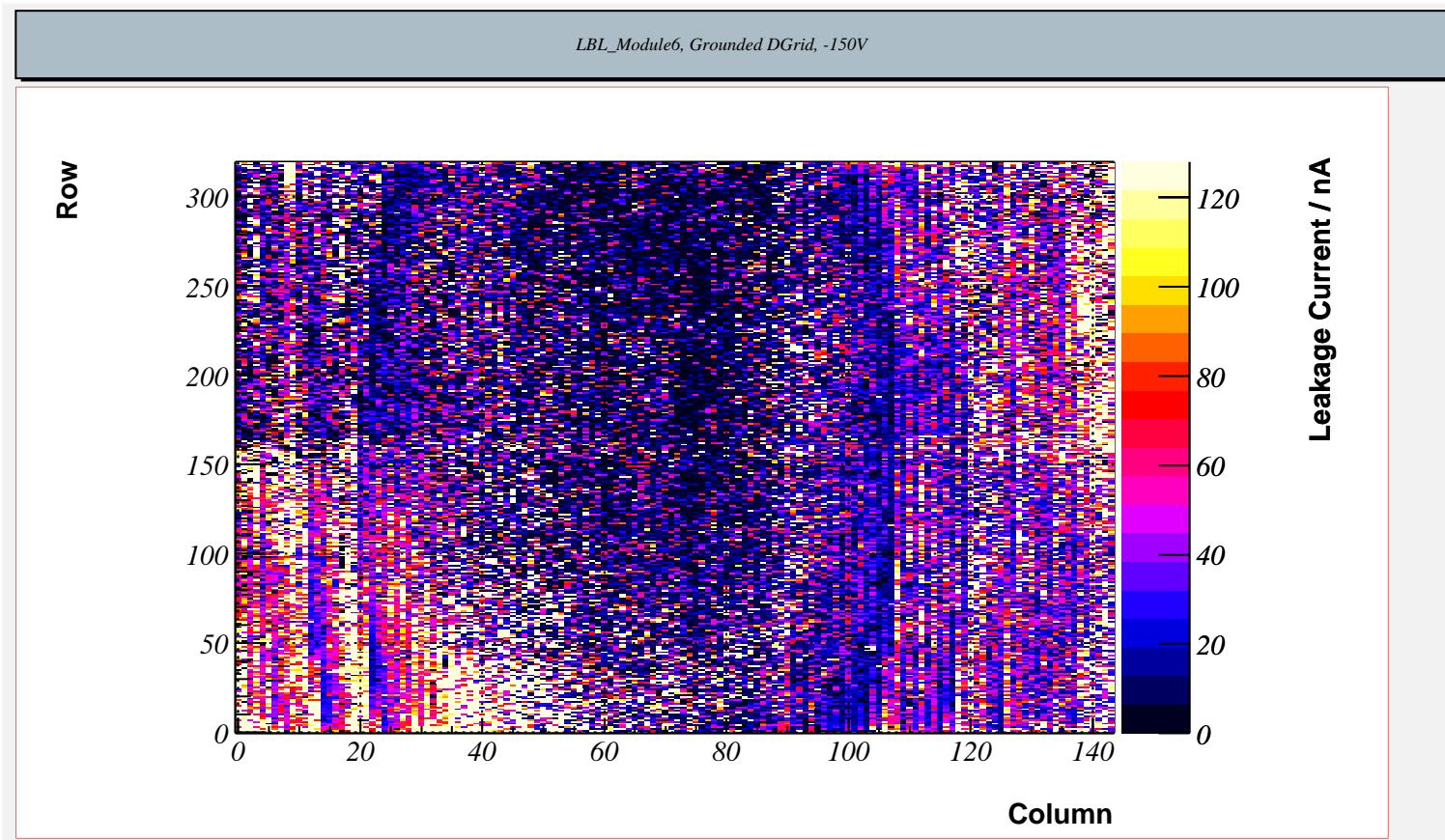
- Extremely large and non-uniform noise distribution in all chips.

- Map of threshold and noise for LBL_6 (AMS/Tesla) after tuning:



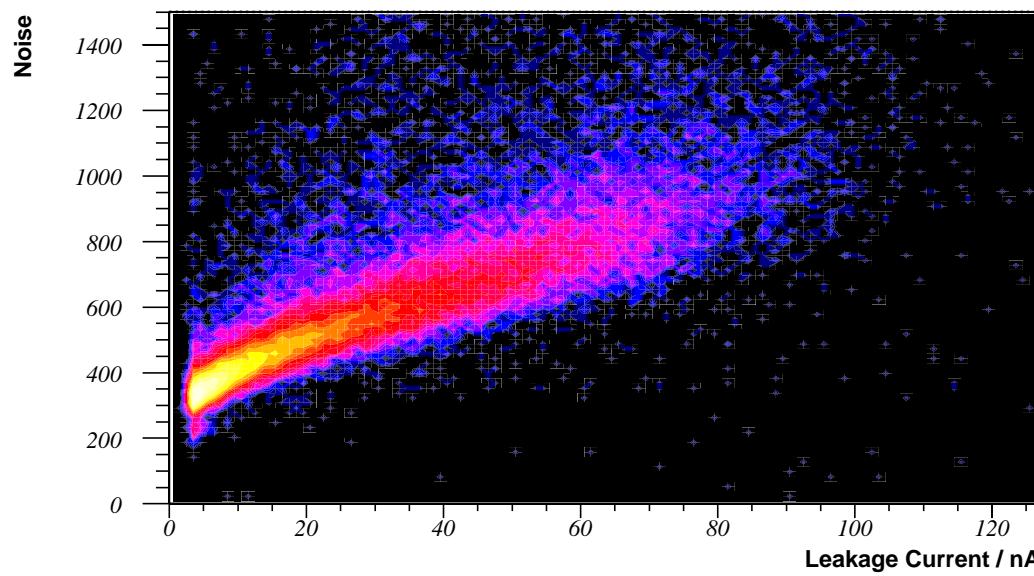
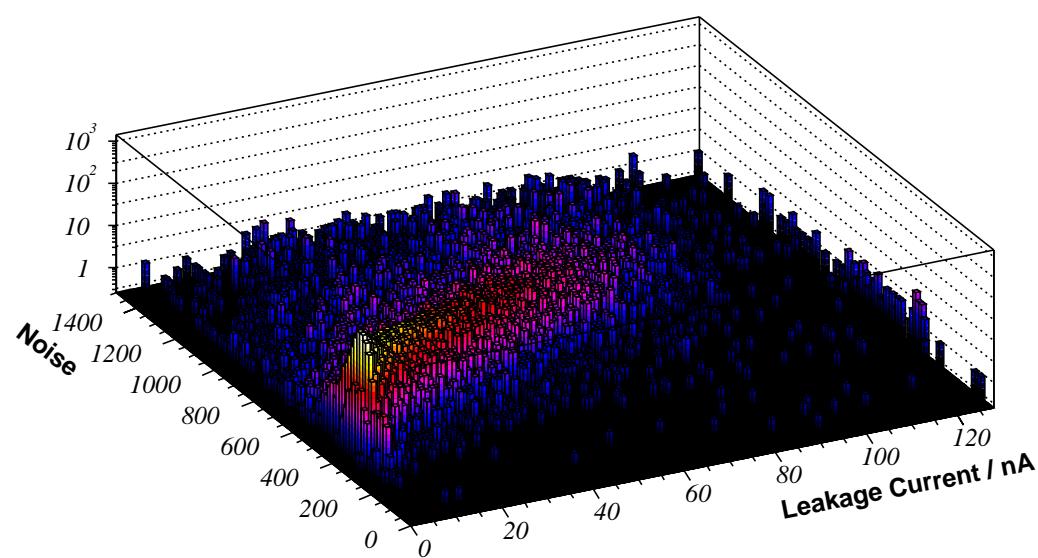
- Noise distribution is non-uniform and sensor related, not FE chip related.

- Leakage current scan for LBL_6 (AMS/Tesla):

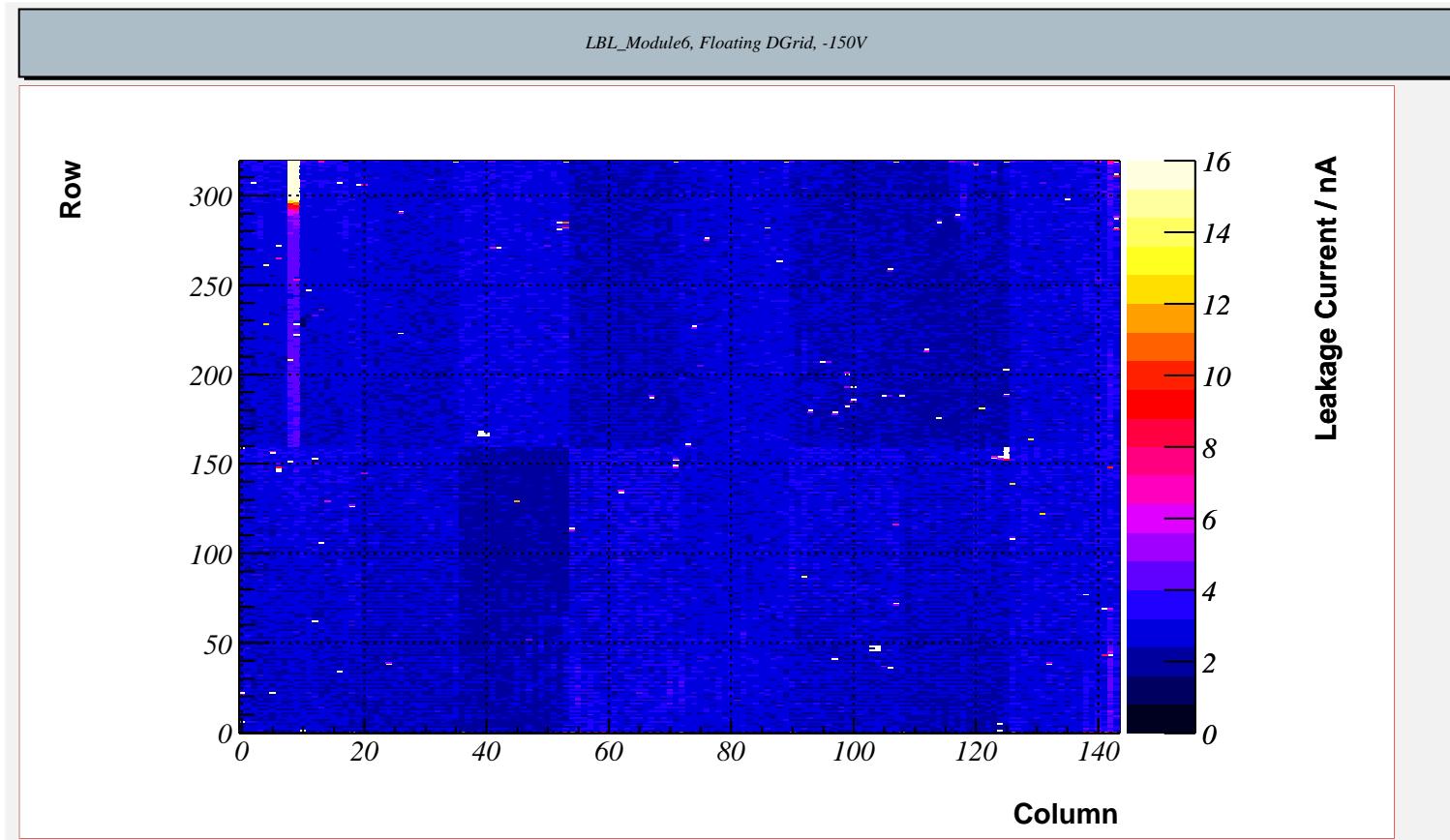


- Observe very large leakage currents, with indications of underlying circular patterns.

- Look at correlation between noise and leakage current in LBL_6 (AMS/Tesla):

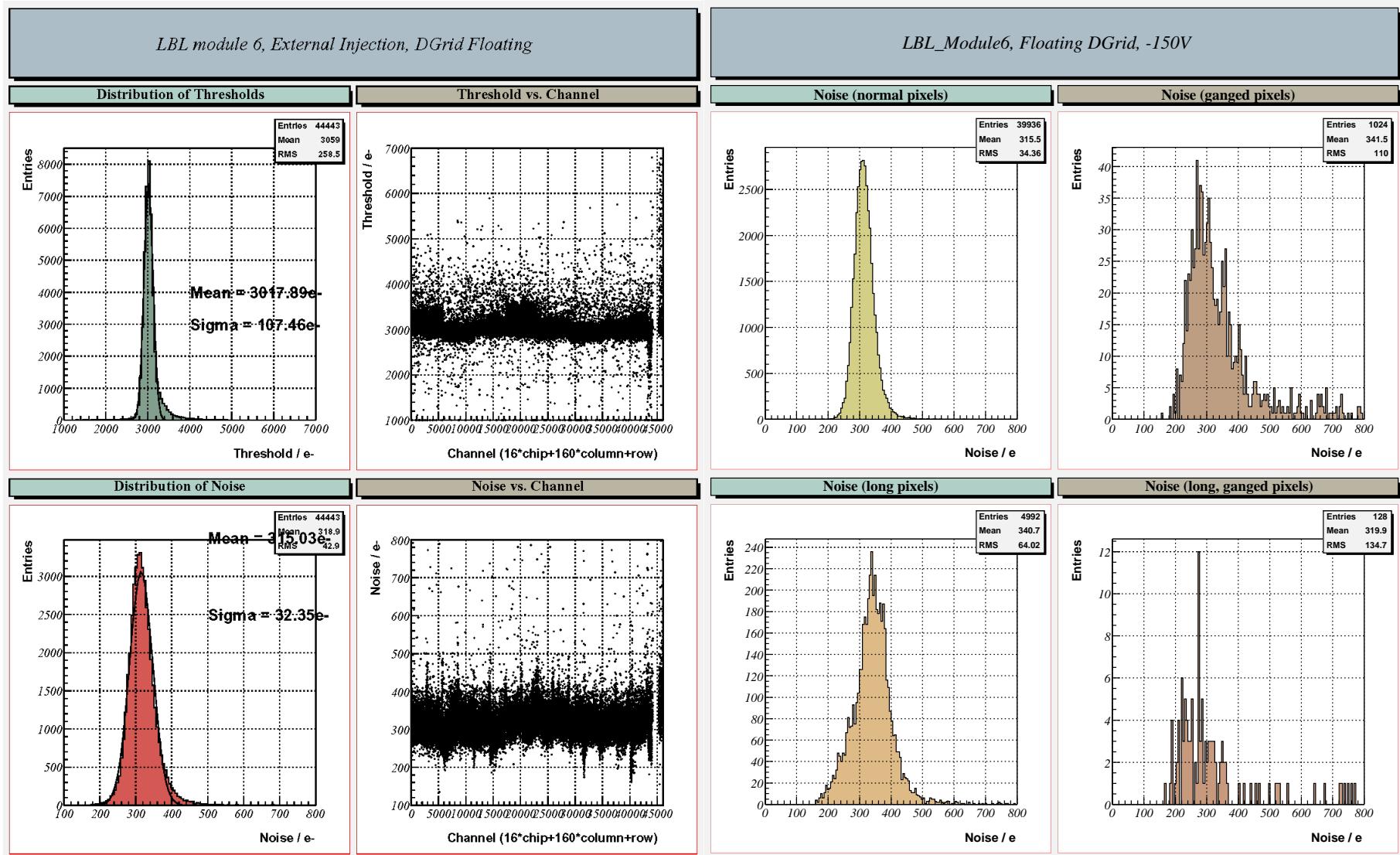


- After removal of all DGrid wire bonds on LBL_6 (AMS/Tesla) module:



- Find very uniform leakage current, although there are a significant number of bad pixels in this assembly...

- Noise distribution for LBL_6 (AMS/Tesla) after bond removal looks normal as well:



- Again, as for other AMS modules, the ganged pixel noise is much lower than in IZM modules.